Thesis
Final
Report

1099 New York Avenue
Washington, D.C.

William Cox
Construction Management
Dr. Michael J. Horman
4/9/2008

William D. Cox

1099 New York Avenue

Construction Management

Washington, D.C.

Project Team

Owner: Tishman Speyer Properties

Architect: Thomas Phifer and Partners

Civil Engineer: Wiles Mensch Corp.

Structural Engineer: Tadjer-Cohen-Edelson

MEP Engineer: Syska Hennesy Group

Lighting Designer: George Sexton Associates

General Contractor: James G. Davis Construction Corp.

Basic Project Information

- 173,260 SF of Premier Office and Retail Space
- 11 stories Above Grade, 4 stories Below Grade Parking
- Design-Bid-Build with CM @ Risk (General Contractor)
- Construction Cost: $31,600,000
- Project Duration: June 2006 through March 2008 (estimated)
- Building features a “fish-scale” glass curtain wall on which each piece of glass lays in a separate plane

Structural System

- Foundation rests on 3,000psi Grade Beams and Spread Footings
- Parking Deck Structure comprised of combination 4”, 8” and 12” reinforced concrete decks
- Building frame is post-tensioned concrete with an Effective Post Tensioning Strength between 100 and 1000 kips

Mechanical and Electrical Systems

- (2) 1440 GPM 500 ton Cooling Towers serve (15) Self-Contained Water Cooled Air Conditioning Units at each level
- VAV Boxes with Reheat Coils distribute air through occupied spaces
- Building Serviced by a 3ϕ, 4-Wire, 460/265 Volt, 4000A Main Bus that steps down through (3) 30KVA, 3ϕ, 460/120V Transformers
- Emergency Power Supplied by (1) 350/438 KW/KVA 480/277V Generator

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Acknowledgements

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James G. Davis Construction Corporation

Bill Moyer	Executive Vice President
Jim Dugan	Senior Vice President
Andy Cecere	Project Manager
Joel Miller	Project Manager
Dave Masters	Senior Superintendent
Dan Hardnock	Senior Estimator

Tishman Speyer Properties

Charles Yetter	Vice President, Design & Construction
Cynthia Bowden	Director, Design & Construction

Syska Hennesey Group

Jim Miller	Associate Partner

Barton Malow Company

Mark Falzarano	AE Services
Corinne Ambler	Project Engineer

ONCORE Construction

Ray Sowers	Vice President

Prospect Waterproofing

Jay Britton	Project Manager

The Pennsylvania State University

Dr. William Bahnfleth	Professor – Mechanical
Dr. Michael Horman	Associate Professor – Construction
Dr. John Messner	Associate Professor – Construction
M. Kevin Parfitt	Associate Professor – Structural
Dr. David Riley	Associate Professor – Construction

Executive Summary

This senior thesis is an in depth study of the new construction project located at 1099 New York Avenue in Washington, DC. Included are research into the sustainable options for the building, two technical analyses focused on the energy efficiency savings & structural considerations for installing a green roof, and a look at mapping & testing the MEP Coordination Process while implementing Building Information Modeling (BIM) technology.

Shortly after 1099 New York Avenue had been designed and construction was underway, Tishman Speyer Properties enacted a new policy that required all new construction projects to achieve a minimum LEED Silver Rating. According to the United States Green Building Council's Reference Guide for Core & Shell Construction, 28 credits must be earned in order achieve the silver rating. The first part of Analysis I determined that the building has already earned 9 of the 28 required credits. The second part is an in depth investigation into 26 other areas where Tishman Speyer could have focused their efforts on sustainability on for this project and provides goals to achieve for future projects. Some of these areas include water conservation, use of recycled content, indoor air quality, and the installation of a green roof.

The effect a green roof can have on a building's energy performance varies according to the composition of the roof layers, the orientation & footprint of the building, and the ratio of that footprint to the total building area. To determine the energy savings a green roof might provide for 1099 New York Avenue, two building energy models were created and the consumptions of source energy were compared. The first model was the building as designed; the second was the building with the insulating properties of a green roof included. It was determined that a green roof could reduce energy usage by 3.54% annually.

The second technical analysis considers the amount of weight that can be added to a structure after installing a green roof. The lower roof area was determined to be structurally sound, but the penthouse roof required a resizing of the slab reinforcement. Cost savings were estimated by being able to eliminate the drop panels with the increased shear strength.

Well into the construction phase of the project, it was noticed that there had been some errors in the MEP Coordination Process as the designs of the different systems were conflicting with each other. This problem was also recognized later in the main lobby area with the decreased plenum space available. The construction depth analysis to a look at the current 2D Design Coordination process from a Lean Production perspective and compared it with the 3D Design Coordination Process through dynamic systems modeling. The process model was then tested by creating a sample model of the lobby space. Findings included a possibility of increased productivity and a 17.3% in the overall project schedule.

Project Overview

1099 New York Avenue is to be Tishman Speyer's new premier office building located in the heart of Washington, D.C. near the newly constructed convention center. The New York based company is looking for the opportunity to establish itself in the D.C. market.

The ground floor will serve as a main lobby for the ten stories of office space above and will include two retail spaces that will have separate street access located on both New York Avenue and 11th street. Below grade will be four levels of parking structure and a fitness center accessible to all future tenants. The primary feature of the building is a state of the art high performance glass curtain wall in which each piece of glass lies in a different horizontal plane. The construction of the 173,260 sq ft structure is projected to cost $31,600,000 and has an expected duration dating from June 2006 to March 2008.

Project Team

Owner – Tishman Speyer Properties
Architect – Thomas Phifer & Partners
Structural Engineer – Tadjer-Cohen-Edelson
MEP Engineer – Syska Hennesy Group
Civil Engineer – Miles Wensch Corporation
General Contractor – James G. Davis Construction Corporation

Client Information

Tishman Speyer Properties is the owner of the project. They consider themselves to be one of the leading owners, developers, operators, and fund managers of first-class real estate in the world. They pride themselves in seeking opportunity where others see difficulties and transforming those opportunities into assets of even greater value. They feel that vertical integration is the key to their success and their ability to envision a broader array of possibilities than others. The project is to be one of Tishman Speyer's premier office buildings in the District from both a design and functional standpoint.

Project Delivery

The delivery method selected by the owner was Design-Bid-Build with a General Contractor (CM @ Risk). This method is preferred on a company-wide scale because Tishman Speyer typically wants control of the design consultants. They do not wish to take on the risks an owner might encounter in a Design-Build delivery. **Figure 1** shows the breakdown of the project team organization.

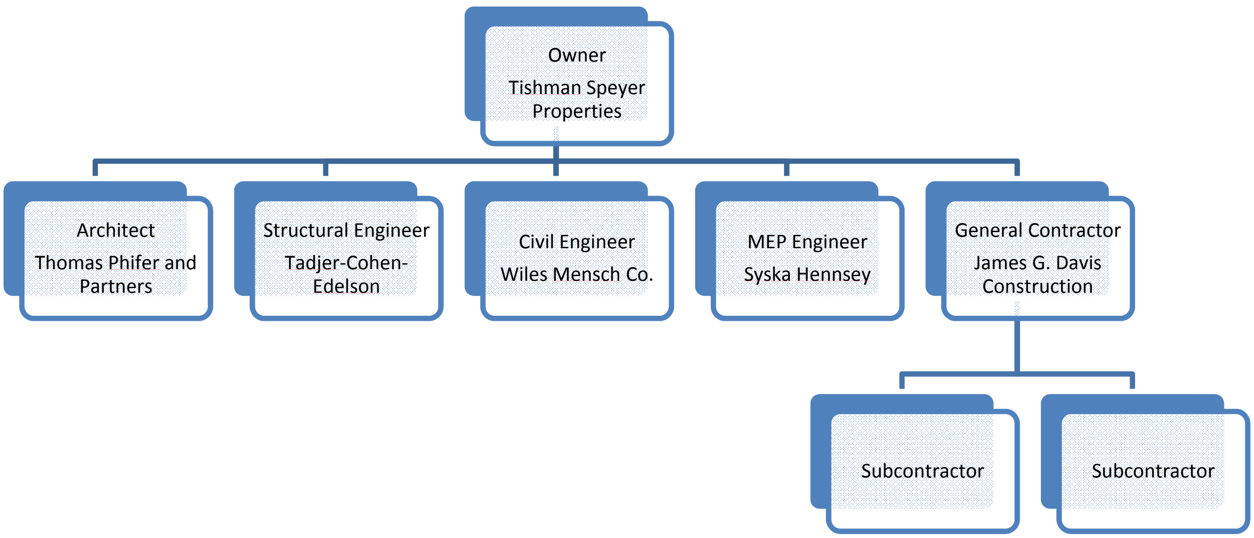


Figure 1 Project Organization Chart

Tishman Speyer holds standard lump sum contracts with the architect and each of the engineers whereas Davis Construction holds a guaranteed maximum price contract. The details of the contract with Davis include a savings clause in which 25% of all savings earned on the project stay with Davis as an incentive to complete the project under budget. No payment and performance bond is required.

With each of the subcontractors, Davis holds a lump sum contract. The doors, frames, and hardware contractor is under a lump sum purchase agreement since they install the materials themselves. Each subcontractor was picked based on the lowest bid with regards to Davis' budget estimate. Every contractor is required to be insured, but bonds were only purchased on the larger contracts ($200,000 or more) to provide cost savings. The major subcontractors are listed below.

Concrete: ONCORE Construction
Electrical: Freestate Electrical Co.
Mechanical: W.E. Bowers
Fire Protection: Strickland Fireproofing
Curtain Wall: Antamex International
Earthwork: National Wrecking

Site Plan and Existing Conditions

The site for the project is located at the corner of 11th Street NW and New York Avenue NW in Washington, D.C. Neighboring on the east side is the Embassy Suites Hotel, a recently constructed 14 story structure. The only space between these two areas is a 10 ft public alleyway. To the north is another active construction site. This project began just weeks after mobilization on 1099 New York Avenue, so careful coordination had to be taken into consideration while excavating.

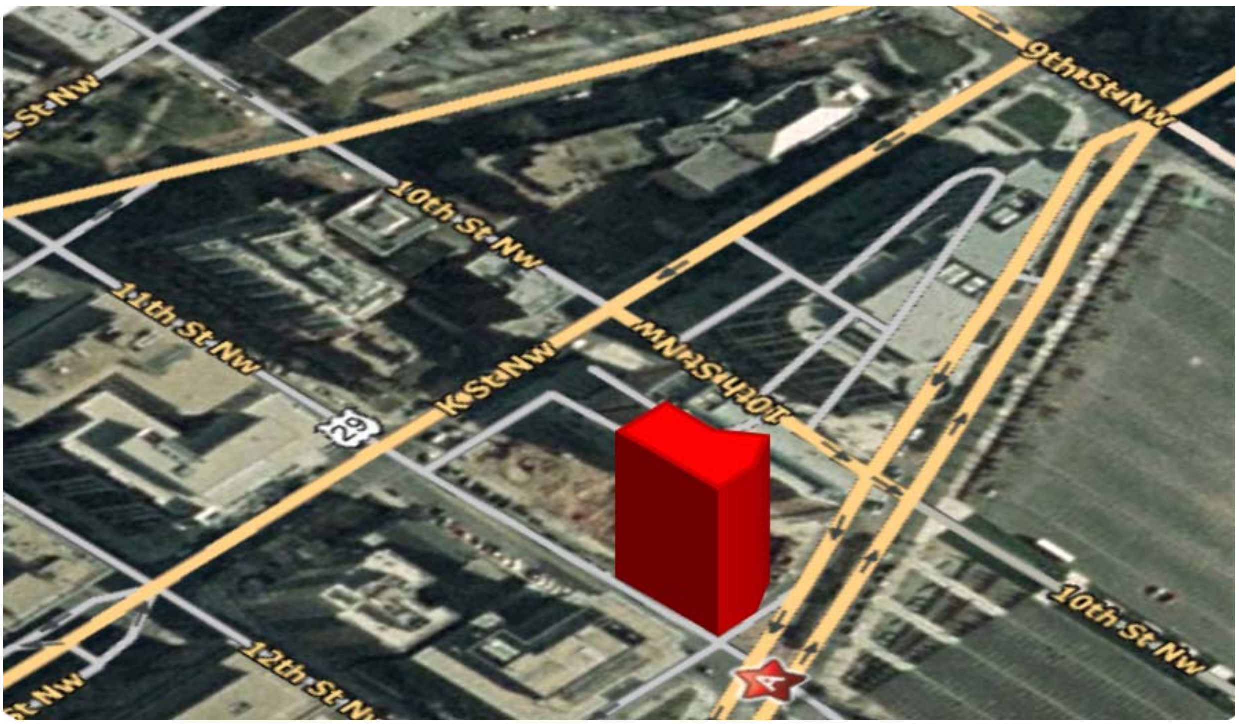


Figure 2 Location of 1099 New York Avenue

Due to a congested site, one of the north bound lanes on 11th Street will be closed for the duration of the project. This will allow for more flexibility in material staging and room for a covered pedestrian walkway. This will provide a steady flow of pedestrian traffic. Because it is a downtown location, parking is scarce and only available at the meters on New York Avenue and the public parking lot across the street.

Gates are positioned at three locations around the site: one at each of the southeast, southwest and northeast corners. Material deliveries are to enter the site via the southwest gate, travel northbound and exit via the northwest gate. This allows trucks to continue through the site and avoid turning around. Unless permission is given, materials will be stored outside.

Dumpsters are also positioned along this driveway for easy access to both the construction workers and the trash removal crews. A detailed site plan can be found in **Appendix A.**

Building Systems Summary

Cast in Place Concrete

The garage levels are short-spanned reinforced concrete slabs varying between thicknesses of 4”, 8” and 12”. The typical bay size is 25’-0” x 30’-0”. Slabs on grade are to be 3,000 psi in strength whereas suspended slabs are 5,000 psi. 8” drop panels at each of the columns are incorporated into the structure.

All slabs above grade are 8” thick and scheduled to be post-tensioned with an effective strength between 100 and 1000 kips. The typical bay above grade is spanned longer and sized at an average of 25’-0” x 40’-0”.

Curtain Wall System

The curtain wall on the west and south facades is a very complex system. It consists of a “fish-scale” frame on which each corner on each piece of glass lies in a separate plane (except for the upper left hand corner). Each panel is constructed of a high performance, low-e coated, insulated glass assembly which rests on structurally glazed aluminum frame. The design of the system was completed by a separate architect and requires its own consulting firm. Because of the great detail required, phasing began before the building permit was even obtained. To keep the project on schedule, construction of the west and south elevations must begin as soon as the superstructure is complete and be erected simultaneously. The system is being fabricated in Toronto and requires considerable coordination during the shipping, staging, and construction process on behalf of the contractor.

Electrical System

The main service feeder for the building enters from the Pepco transformer vaults on New York Avenue at the B2 level. The service is a 3-Phase, 4-Wire, 460/265 Volt, 4000A Main Bus that steps down through (3) 30KVA, 3-Phase 460-208/120 V Transformers. The power supply for the retail area is separate from that of the office space. Emergency power is supplied by a 350/438 KW/KVA 480/277V Generator located at the penthouse.

Mechanical System

The primary mechanical room for this project is located at the penthouse. Located there are (2) 1440 GPM 500 ton Cooling Towers which serve 15 Self-Contained Water Cooled Air-

Conditioning Units throughout the building. The AC unit at the penthouse provides conditioned outdoor air to the smaller units at each of the 15 levels at a rate of almost 30,000 CFM. From each of these units, Variable Air Volume (VAV) Boxes with reheat coils distribute air throughout the occupied spaces.

Transportation

The Building is served by four traction elevators at the core of the building. There are three passenger cars rated for a capacity of 3,500 lbs. whose hoist way rises from the B4 level to the 11th floor. The one service car is rated for 4,500 lbs. and serves all levels, including the mechanical penthouse. All four elevator systems are gearless and do not require a machine room. They are each rated as Class A Loading and are contracted to travel at a speed of 350 FPM.

Project Schedule Summary

The design of the project began in early 2004 after the site was purchased from Hertz Rental Company. Construction services had been procured by early 2006.

Construction activity on the project began on June 22, 2006. Demolition of the existing 2 story structure was required as well as the removal of the surrounding sidewalk areas. Demolition took 26 days and was completed by early August. Excavation began at the end of August shortly before all of the soldier beams had been driven.

Foundation work was scheduled to begin once excavation was completed in mid December. Immediately following is the forming, reinforcing, and pouring of the garage level. The substructure was complete to grade by early April. The superstructure ensued and was complete 4 months later in August.

Curtain wall construction began once the superstructure had been completed and was expected to be finished as of October 30, 2007. Because of its complexity, the 11th Street and New York Avenue façade elevations were constructed simultaneously in order to enclose the building sooner. Once weatherproofed, interior core construction was only expected to take 3 months. This includes the monumental lobby at the ground floor. Substantial Completion was scheduled for March 3, 2008. A summary of the key project dates and details for the major systems are listed below.

Key Project Dates	
Issue to proceed	6/22/2006
Substructure Construction Begins	12/12/2006
Excavation Complete	12/20/2006
Superstructure Construction Begins	4/10/2007
Interior Construction Begins (B4 Level)	6/6/2007
Curtainwall Construction Begins	6/14/2007
Topping Out	8/24/2007
Sitework Complete	11/15/2007
Tenant Contractors Granted Access	11/21/2007
MEP Complete	1/21/2008
Substantial Completion	3/6/2008

A detailed project schedule can be seen in **Appendix B.**

Structural

The building is broken down into four pour zones below grade and three above based on the amount of concrete ONCORE Construction can pour in the period of one day. Concrete placement begins at the north end of the site at each level and moves south. Work on the substructure was scheduled to commence on 12/12/2006 and be complete by 8/24/2007.

Task	Duration	Start	Finish
Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #1	11 days	4/10/07	4/24/07
Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #2	11 days	4/16/07	4/30/07
Columns/Interior Walls to Next Level	12 days	4/19/07	5/4/07
Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #3	11days	4/20/07	5/4/07

Table 1 Typical Structural Sequencing

Façade

Construction of the Façade was set to begin on 6/14/2007. It was necessary to begin prior to the completion of the superstructure because each façade takes approximately 100 days to be constructed and building enclosure was required before the winter season. The south elevation was expected to take the longest to complete.

Interior Construction

Interior construction moves from the inside out. Mechanical and plumbing trades were the first to begin. As they progress outwards from the core, the fire protection and drywall contractors begin, followed by the electrician. The only trade performing work on the perimeter of the building is the drywall contractor. Since this is a base build project, tenants were responsible for their own interior construction sequencing. Information on the tenant construction schedule beyond the start date of 11/21/2007 was not provided.

Task	Duration	Start	Finish
Hang Risers/Install Core Mechanical System	13	6/25/07	7/11/07
Install Core Plumbing/Pipe Fixtures	73	6/25/07	10/2/07
Install/Hydro Core Sprinkler	12	7/5/07	7/20/07
Frame/Hang Core Walls and Ceiling	42	7/30/07	9/25/07
Install Electrical/Fire Alarm	44	8/2/07	10/1/07
Install Toilet Partitions and Counters	49	8/2/07	10/8/07
Install Doors and Hardware	3	9/12/07	9/14/07
Frame, Hang, Finish Perimeter Drywall	42	10/11/07	12/7/07

Table 2 Typical Interior Construction Sequencing

Project Cost Summary

The building construction cost for the project as reported by Davis Construction is approximately $31,600,000. This amount does not include land costs, site work, or design fees that are the responsibility of the owner. The total project cost to Tishman Speyer Properties is an estimated $65,000,000. This number includes all costs including construction, design and land acquisition. With an approximate value of 173,260 square feet of above grade space, the construction cost and total project cost are roughly $182.38/sq ft and $375.16/sq ft respectively. This analysis as well as a breakdown of the building's major system cost can be seen below in **Table 3**.

Building System	Cost	Cost Per SF (173,260 SF)
-	-	-
Overall Project	**$65,000,000.00**	**$375.16**
Building Construction Costs	$31,600,000.00	$182.38
Owner's Additional Costs	$33,400,000.00	$192.77
Structural	**$9,056,926.00**	**$52.27**
Concrete	$7,500,000.00	$43.29
Masonry	$836,926.00	$4.83
Miscellaneous Metals	$445,000.00	$2.57
Roofing	$275,000.00	$1.59
Curtainwall	**$5,405,662.00**	**$31.20**
Antamex Glazing	$5,205,662.00	$30.05
UAD Storefront Glazing	$200,000.00	$1.15
Finishes	**$1,005,397.00**	**$5.80**
Drywall	$826,325.00	$4.77
Ceramic & Stone Tile	$111,200.00	$0.64
Carpet and Resilient Tile	$6,372.00	$0.04
Paint	$61,500.00	$0.35
Elevator	**$1,198,700.00**	**$6.92**
Elevators	$1,173,700.00	$6.77
Parking Attendant Lift	$25,000.00	$0.14
Mechanical	**$4,090,000.00**	**$23.61**
HVAC/Plumbing	$3,600,000.00	$20.78
Sprinkler	$490,000.00	$2.83
Electrical	**$1,895,000.00**	**$10.94**
Electrical Systems	$1,895,000.00	$10.94

Table 3 Project Cost Breakdown

Analysis I – Achieving Sustainability

Background

Tishman Speyer Properties is among the elite real estate owners, developers, operators, and fund managers of first-class real estate in the world. They pride themselves in seeking opportunity where others see difficulties and transforming those opportunities into assets of even greater value. They feel that vertical integration is the key to their success, as well as their ability to envision a broader array of possibilities than others. 1099 New York Avenue is to be one of Tishman Speyer's premier office buildings in the District of Columbia from both a design and functional standpoint.

Efforts towards green construction have had an increased concentration as of late from both the design and construction perspectives. With energy conservation in the national limelight, a substantial amount of research has been made in the construction industry. This is extremely important considering that buildings consume a significant amount of the energy produced each year.

Problem

Shortly after construction on 1099 New York Avenue began, Tishman Speyer Properties adopted a new company wide policy which stated that all new projects were to achieve at least a Leadership in Energy and Environmental Design (LEED) Silver Rating. The policy was intended to keep Tishman Speyer at the forefront of the real estate industry as one of the leaders in green construction. The primary focus of their policy is centered around the recycling of waste, the use of easily renewable materials, the implementation of energy efficiency and water conserving measures, and the establishment of a healthy and productive indoor environment. Although 1099 New York Avenue is to be Tishman Speyer's premier office building in the District of Columbia, it was not originally designed to be a sustainable building. Therefore, in order to achieve this rating the design and construction methods have to be altered.

Objective

The objective of this analysis is to investigate the variety of sustainable practices currently being utilized in the industry and determine which aspects of 1099 New York Avenue can be enhanced to achieve the LEED Silver Rating for Core and Shell Construction. This rating requires a minimum of 28 credits to be earned.

Analysis Part I

Evaluation of Current Credits Obtained

Although 1099 New York Avenue was not designed with sustainability in mind, there are still a few aspects of the project that meet the requirements of the United States Green Building Council. (Please note that all LEED Criterion is based on the Core and Shell Development Version 2.0 Reference Guide since this was the most current edition at the time of design and construction.)

Credit SS 1 – Site Selection
1099 New York Avenue was developed on a site that was previously occupied by a two story rental car office. It is not located on undeveloped farmland or within a 100 foot radius of any wetlands as defined by United States Coded of Federal Regulations 40 CFR, Parts 230-233 and Part 22.

Credit SS 4.1 – Public Transportation Access
The project site is located within the maximum ¼ mile radius from one or more stops for two or more public bus lines. There is a bus stop located at the corner of 11th Street NW and New York Avenue NW that serves six separate transit routes.

Credit SS 7.1 – Heat Island Effect (Non-Roof)
100% of the parking spaces for the building are located underground. This exceeds the minimum of 50% for the credit.

Credit WE 1.1 and Credit WE 1.2 – Water Efficient Landscaping
The tree planters being installed along 11 Street NW and New York Avenue NW do not require any form of permanent irrigation systems.

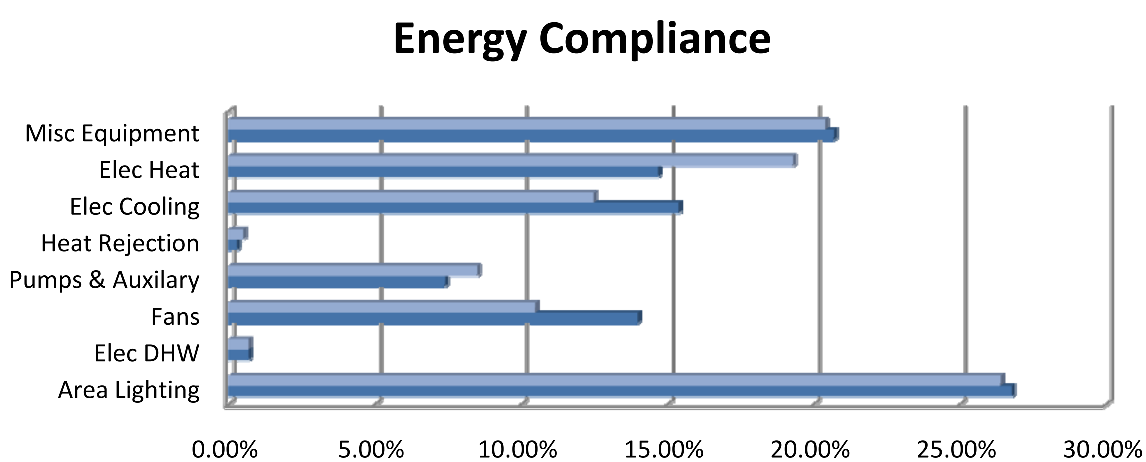
Energy and Atmosphere Prerequisite 1 (No Credit Given)
This prerequisite is concerned with the commissioning of the building energy systems. In order to fulfill this requirement, an individual (separate of the design and construction management teams) must be designated as the Commissioning Authority to lead, review and oversee the completion of the commissioning process. The owner must also

document their own commissioning requirements for the project from which the design team shall develop the Basis of Design.

Currently W.E. Bowers, the Mechanical Contractor, is responsible for the commissioning process and have appointed a person who is to be responsible for overseeing the process. The commissioning requirements for the project have been included in the construction documents by Tishman Speyer and the design team. They are under Division 19 in the Construction Specifications.

Energy and Atmosphere Prerequisite 2 (No Credit Given)

This prerequisite requires that the energy systems for the project be designed to comply with the mandatory provisions of ASHRAE/IESNA Standard 90.1 (without addenda). As seen in Chart 1.1 below, the designed system meets the ASHRAE 90.1 energy code by 0.95%.



	Area Lighting	Elec DHW	Fans	Pumps & Auxilary	Heat Rejection	Elec Cooling	Elec Heat	Misc Equipment
As-Designed	26.40%	0.70%	10.50%	8.50%	0.50%	12.50%	19.30%	20.40%
ASHRAE 90.1	26.80%	0.70%	14.00%	7.40%	0.30%	15.40%	14.70%	20.70%

Chart 1.1 visualizes the buildings compliance with ASHRAE 90.1

Energy and Atmosphere Prerequisite 3 (No Credit Given)

The prerequisite refers to the refrigerant management on the project. The criterion states that no CFC-based (chlorofluorocarbons) refrigerants are to be used on the project. The project complies since the only refrigerant specified to be used is R-22, a hydrochlorofluorocarbon that causes significantly less depletion of the ozone.

Credit MR 5.1 & Credit MR 5.2 – Regional Materials

Credit 5.1 requires that 10% of the materials or products (based on value) be extracted and produced within a 500 mile radius of the project site. Credit 5.2 requires that 20% of the materials or products (based on value) be extracted or produced within the same 500 mile radius of the project site. The LEED Reference Guide for Core and Shell Development states that the cost of materials for the project can be estimated as 40% of the total cost of construction for the Construction Specification Institute's (CSI) Divisions 2-10. (Mechanical, Electrical, and Plumbing Costs are not to be included in this calculation)

The total cost of construction for Divisions 2-10 for 1099 New York Avenue is $22,875,000. The total cost of materials is therefore estimated to be **0.4 x $22,875,000** which equals **$9,150,000.**

The cementitious material, aggregate, and reinforcement for the structural system are all extracted and produced within the required 500 mile radius and their value of **$1,972,937** is **21.56%** of the total material cost which exceeds the required 20% of total cost for regional materials. See **Table 1.1** below for calculations.

Material	Weight (ton)	Unit Cost	Total Cost	Manufacturing Location	Dist. from Proj. (mi)	Percent of Material Cost
NewCem Additive	1,130	$95.00	$107,350.00	Sparrows Point, MD	47	1.17%
Portland Cement	3,389	$135.00	$457,515.00	Union Bridge, MD	70	5.00%
Fine Aggregate	8,833	$14.00	$123,662.00	Chase, MD	57	1.35%
Coarse Aggregate	12,325	$14.00	$172,550.00	Frederick, MD	51	1.89%
Steel Reinforcing	1,065	$1,044.00	$1,111,860.00	Marion, OH	466	12.15%
		Total	**$1,972,937.00**		**Total**	**21.56%**

Table 1.1 Summarizes the manufacturing location and cost for the cast in place concrete materials

Indoor Environmental Quality Prerequisite 2 (No Credit Given)

This prerequisite has already been met considering smoking is prohibited in all indoor facilities throughout the District of Columbia.

Credit EQ 8.1 & Credit EQ 8.2 – Daylight and Views

Because of the glass curtain wall and the open floor plan of a core and shell building, the project meets the daylight requirements according to the procedures outlined in Option 1, Glazing Factor Calculations. The calculations are included in **Appendix C.**

Analysis Part II

Evaluation of Credits to be Obtained

As you can see above, after extensive research the project is only eligible to receive 9 of the 28 credits required for LEED Silver. The second portion of my analysis will include suggestions for different courses of action that could have been taken on this project to obtain the balance of credits and will be proven useful as guidelines for future Tishman Speyer projects.

Credit SS 4.2 – Bicycle Storage and Changing Rooms

The building is already equipped with a fitness center which houses locker rooms containing showering facilities. If secure bicycle racks were to be provided within 200 yards of the building's entrance, a credit could be earned. The amount of bicycle racks to be installed must equal at least 3% of the building's full time occupancy. Since all tenant spaces have yet to be leased, the default occupancy loads provided in Appendix 1 will be substituted.

Default Occupancy Load (General Office) = **1 person / 250 sq. ft.**
Gross area per office floor = **13,037 sq. ft.**
Total area = **130,370 sq. ft.**

Full Time Expected Occupancy = 130,370 sq. ft. / 250 sq. ft. / 1 person = 522 persons

Number of Storage Stalls Required = 0.03 x 522 persons = 16

Credit SS 4.3 – Low Emitting and Fuel Efficient Vehicles

Encouraging commuters to travel in fuel efficient vehicles is considered sustainable construction since it is an effort to reduce the amount pollution in the environment. A LEED credit can be earned by allotting 5% of the available parking spaces as priority parking spots for fuel efficient vehicles.

Total number of parking spots = 95
Required preferred parking = 0.05 x 95 = 5 parking spots

The building contains a total of 95 parking spaces, thus only 5 spots would have to be reserved.

<u>Credit SS 6.1 Stormwater Design & Credit SS 7.2 – Heat Island Effect (Roof)</u>
Credit SS 6.1 and Credit SS 7.2 can both be obtained with the addition of a green roof to over 50 % of the current roof area above the eleventh floor and the mechanical penthouse. The roof is already designed to have public access, why not improve its function?

Green roofs have many ecological benefits and serve as enhanced protection for conventional waterproofing systems on a building. They are divided into two different categories, extensive and intensive. Extensive systems tend to be less than 6 inches in depth and are designed to satisfy engineering performance requirements. Typical plant life is small shrubs, grasses, and mosses. Intensive systems tend to be more elaborate and will contain trees and larger brushes. They generally create more of a structural burden than the shallower system. With this in mind, an Extensive Green Roof would be the most appropriate addition to 1099 New York Avenue.

Some of the ecological benefits a green roof can provide for the project include better control of storm water runoff, mitigation of the urban heat-island effect, prolongation of the service life of roofing materials, energy conservation and improvement of the aesthetic environment.

Storm Water Runoff
Runoff over paved surfaces, such as the concrete pavers on the current roof, tends to be rapid and contributes to destructive flooding, erosion or pollution. The granular consistency of a green roof can slow this process through retention and detention. A typical extensive green roof can retain 2 inches of rainfall, whereas a conventional roof system can only retain 0.40 inches. There may not be as great of a concern for flooding or erosion from a roof in an urban environment, but a reduction in flow allows for a decrease in size for the storm water management system in the building. This means smaller pipe sizes can be used, which in turn provides smaller slab penetrations and an increase in valuable plenum space. Also, a smaller surge will be experienced on the building's sump pumps and the city's sewer and storm water systems during a peak storm. Reductions of up to 65% of runoff have been measured in the District of Columbia. The current impermeable area used in calculation for the site is 22,000 sq ft. In order to earn credit SS 6.1, the volume of runoff must be decreased by 25% of the pre-development runoff rate. The addition of a green roof covering at least 50% of

15,800 sq ft (the building footprint) will reduce the impermeable area by 36% and in turn reduce the flow of runoff. If the following equation was used,

(Runoff Rate = Runoff Coefficient x Average Intensity of Rainfall x Impermeable Area)

the runoff rate for the 1 year and 2 year 24-hour storms will be reduced by the same 36%. See **Figure 1.1** below for a sample reduction measurement.

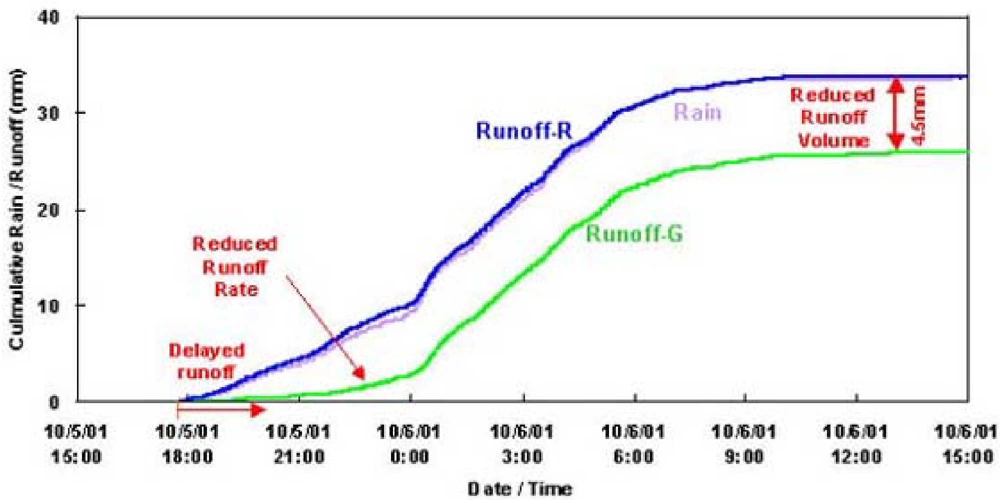


Figure 1.1 from the National Research Council's Institute for Research in Construction shows the decreases in runoff as measured during a 15 hour period in October of 2001. The graph also indicates that green roofs provide a delay in storm water runoff which prevents surging.

Urban Heat-Island Effect

The Urban Heat-Island Effect is the temperature difference between an urban area and its surrounding countryside. It is largely due to the large concentration of hard and reflective materials on roofs that absorb solar radiation and release it into the atmosphere as heat. Reduction of this effect can decrease the amount of smog as well as particle matter in the air. It also plays a role in the reduction of greenhouse gas emissions such as sulfur dioxide, nitrogen dioxide and carbon monoxide. Green roofs do this by reducing the air conditioning use and peak load capacities, decreasing outdoor temperatures through evaporative cooling, and reducing collection of particles in the atmosphere by plant leaves.

Service Life of Roofing Materials

The multiple layers of green roofs preserve the roof materials underneath by protecting against mechanical damage from humans and wind blown elements. It also shields against ultra-violet radiation and neutralizes temperature extremes that may cause cracking from expansion and contraction. Modern green roof systems have not been installed for a period longer than 35 years; however, researchers expect that the lifespan will be approximately 50 years before any significant repairs will have to be made. Although the initial cost may be greater, this life expectancy exceeds the current span of roofing materials by a factor of 2-3. The current roofing system on 1099 New York Avenue is only to be warranted for 20 years.

Energy Conservation

Green roofs serve as a more complex form of insulation than traditional systems. Since cooling is a more energy intensive process than heating, the majority of conservation from green roofs is experienced during the summer when air conditioning loads are at their peak. This is when the capacity to reduce the heat flow in a building is the most beneficial. Please see **Analysis II** for an in depth calculation of the building's peak load requirements following the installation of a green roof system.

Improvement of the Aesthetic Environment

Green roofs accessible to the public in commercial environments can provide enhanced property values as well as increased job satisfaction for all employees in the building. Potential clients and future workers will appreciate the garden atmosphere as well as a skylight view of the nation's capital atop their own office building. Not many developments or establishments are able to provide such a setting for its occupants in such a dense urban area.

Re-Greening Washington, DC

The American Society of Landscape Architecture (ASLA) has recently proposed a movement under the name of the Casey Trees Endowment Fund. The effort is focused on quantifying the storm water and air quality benefits of green roofs in Washington, DC. The organization states that DC does not meet federal water quality standards for the Anacostia, Potomac, and Rock Creek Rivers and is not meeting federal air quality standards for ground-level ozone and particulate matter. Population, however, is still on the rise as well as the demand for construction. Their goal is to have 80% of all proposed buildings install green roofs and 20% of all existing buildings that are classified as "green roof ready" install green roofs as their current roofing systems require repair or replacement. The Casey Trees Endowment Fund states that this plan would provide 21,700,000 square feet of green roofs inside the district if it is followed through with and adopted by DC Government. The following projections in benefits are to be expected:

- 30 million gallon increase in the city's storm water storage capacity
- 430 million gallons of rainwater stored of the course of a year
- 1.7% reduction in runoff citywide
- 15% decrease in the number of combined sewer overflows discharged each year in to the city's river
- Annual removal of 16.8 tons of air pollutants
- Annual removal of 6.0 tons of ground-level ozone
- Annual removal of 5.7 tons of particles from the air

Credit SS 9 – Tenant Design and Construction Guidelines

As part of Tishman Speyer's policy for achieving sustainability, there are certain guidelines that are written into lease agreements that tenants must follow.

- All contractor requests are to include alternative material with minimum percentages of recycled content
- All contractor requests are to include alternatives for low Volatile Organic Compounds (VOCs) in paints, sealants and adhesives
- Standard specifications for green materials will be distributed to assist in sustainable procurement and contracting

In addition to these requirements, Tishman Speyer must also include guidelines that educate and aide the tenants in other areas of sustainable design and construction. As part of these guidelines, a description of the sustainable measures taken on the core and shell construction that delineates the project's intent and objectives for LEED accreditation must be included. The proposed LEED credits in this analysis that are applicable to the project and need to be addressed include:

- Water Use Reduction
- Optimizing Energy Performance (Lighting Power, Controls, & HVAC)
- Energy Use and Metering
- Measurement & Verification
- Construction IAQ Management
- Indoor Chemical and Pollutant Control
- Controllability of Systems
- Thermal Comfort
- Daylighting & Views
- Commissioning

Credit WE 3.1 – Water Use Reduction

In order to obtain this credit, water efficiency within the building must be reduced by 20% as compared to the baseline established by the Energy Policy Act of 1992 –

Standards for Plumbing Fixture Water Usage. Those baseline values can be seen in **Table 1.2** below.

Fixture	Energy Policy Act of 1992 (and as amended) Standards for Plumbing Fixture Water Usage
Water Closet (gpf)	1.60
Urinals (gpf)	1.00
Showerheads (gpm)	2.50
Faucets (gpm)	2.20
Faucet Replacement Aerators (gpm)	2.20
Metering Faucets (gal/cy)	0.25

Table 1.2 Baseline values for Plumbing Fixture Water Usage

With the exception of fixture P-3A, the typical lavatory faucet in the building, none of the specified fixtures are below the maximum flow rates outline by the EPA. In order to achieve the 20% reduction in water usage, alternative fixtures by the same manufacturer that provided a lower maximum flow rate were selected as replacements.

- **Change:** Fixture P-3B (ADA Approved Lavatory Faucet) was specified as Chicago Faucets, 786-E3-245 and had a maximum flow rate of 2.2 gpm. It was replaced by a similar model made by Kohler, K-7313-K, that has a maximum flow rate of 2.0 gpm.
  Cost: The Chicago Faucet is listed as $273.27. Kohler K-7313-K is listed as $183.15 per fixture. A total savings of $1,980.44 for 22 fixtures.
- **Change:** Fixtures P-6 and P-6A (Shower Heads) were specified as Powers, e425, and had maximum flow rates of 2.5 gpm. They were replaced by Delta, 11W243, a shower head with a maximum flow rate of 2.1 gpm.
  Cost: The Powers e425 is listed as $364.99 whereas the Delta 11W243 is listed as $272.09. A total savings of $371.60 for 4 fixtures.
- **Change:** Fixtures P-1 and P-1A (Water Closets) were specified as Sloan, Royal Optima 152, with maximum flow rates of 1.6 gal/flush. They were replaced with a new automated dual flush model by Sloan Eco, 8313-1.6/1.1 with an average flow rate of 1.2 gal/flush. The flushometer can be seen in **Figure 1.2** below.
  Cost: The Royal Optima is listed as $707.86 whereas the Sloan Optima G2-8186 can be purchased in tandem with the Eco 8313-1.6/1.1 Retrofit Conversion Kit can be purchased for an additional $701.82. A total savings of $332.20 for 55 fixtures.

Figure 1.2 The Sloan Royal Optima. As described by Sloan, the user enters the beam's effective range, 2 to 42 inches, the beam is reflected into the Scanner Window to activate the Output Circuit. Once activated, the Output Circuit continues in a "hold" mode for as long as the user remains within the effective range of the sensor. Once a user is detected, if the user leaves in 65 seconds or less, a reduced flush of 1.1 gpf/4.2 Lpf will automatically initiate. If the user stays longer than 65 seconds, a full flush of 1.6 gpf/6.0 Lpf will automatically initiate when the user leaves. The circuit automatically resets and is ready for the next user.

Tables 1.3 and 1.4 below display the calculations for the water conservation experienced from the alternative fixtures.

Flow Fixture	Daily Uses	Flow Rate (GPM)	Duration (sec)	Occupants	Water Use (gal)
Lavatory Faucet P-3A	3	2.2	12	522	689
Lavatory Faucet P-3B	3	2.2	15	522	861
Shower Faucet P-6	0.1	2.5	300	522	653
Shower Faucet P-6A	0.1	2.5	300	522	653
Flush Fixtures			**Duration (Flush)**		
Flushometer P-1 & P1-A (male)	1	1.6	1	261	418
Flushometer P-1 & P-1A(female)	3	1.6	1	261	1,253
Flushometer P-2A (male)	2	1.0	1	261	522
Flushometer P-2A (female)	0	1.0	1	261	0
		Total Daily Volume (gal)			5,048
		Annual Work Days			260
		Total Annual Volume			**1,312,412**

Table 1.3 Shows the current schedule water usage for the building.

Flow Fixture	Daily Uses	Flow Rate (GPM)	Duration (sec)	Occupants	Water Use (gal)
Vola HV1/150 (as Designed)	3	1.0	12	522	313
Kohler K-7313-K	3	2.0	15	522	783
Delta 11W243	0.1	2.1	300	522	548
Delta 11W243	0.1	2.1	300	522	548
Flush Fixtures			**Duration (Flush)**		
Sloan 8313-1.6/1.1 Dual Flush	1	1.2	1	261	313
Sloan 8313-1.6/1.1 Dual Flush	3	1.2	1	261	940
Sloan Royal Optima 195 - 0.5 ES-S	2	1.0	1	261	522
Sloan Royal Optima 195 - 0.5 ES-S	0	1.0	1	261	0
		Total Daily Volume (gal)			3,967
		Annual Work Days			260
		Total Annual Volume			**1,031,472**

Table 1.4 Shows the scheduled usage after the addition of more efficient fixtures.

As calculated in the tables above, the baseline volume annual water usage for 1099 New York Avenue is observed at **1,312,412 gallons**. With the installation of the more efficient fixtures in lieu of the specified fixtures the annual water usage becomes **1,031,472 gallons.** This can be calculated as an average savings of **280,940 gallons** per year, or **21.4%,** which meets the minimum of 20% for the credit. The current rate for water usage in the District of Columbia is **$2.14/ccf**. This would mean that Tishman Speyer and their future tenants would save approximately **$400** annually on their water utility.

Credit EA 1 – Optimize Energy Performance

The intent of earning this credit is to increase the level of energy performance above the baseline established in ASHARE 90.1 and in turn, reduce the environmental and economical impacts associated with energy usage. To earn one point in this category, the project must obtain a minimum of 10.5% in energy cost savings. An additional point will be given (up to 8 points total) for each 3.5% of savings. This can be calculated by performing a Building Energy Simulation and comparing the results with the baseline model. The default energy cost is 25% of the total energy cost for the baseline building. As mentioned in the first part of this analysis, 1099 New York Avenue exceeds the baseline performance by 0.95%.

Optimizing energy performance generally requires decreasing the demand on the HVAC System and in turn the load for sizing the equipment. Decreasing the load can be as simple as the changing design of the lighting or the types of computer monitors that are to be used. Down lighting is preferred as well as increased task lighting. Occupancy sensors during off hours also contribute to a reduced load. In terms of office equipment, flat panel LCD computer monitors produce the least amount of heat. On the other hand some solutions can are more complex such as monitoring the efficiency of the building envelope. 1099 New York Avenue is entirely glass on its South and West elevations. This can aide with heating and lighting loads, but it makes it more difficult to cool spaces in the summer. Adding automated solar shades that function based on the sun's position and time of day, in combination with dimming ballasts controlled by photosensors, can reduce lighting levels by approximately 20%. Increasing the air space between the panes of glass or enhancing the glazing so that it has a lower U-Value can provide better insulation of the curtain wall.

As mentioned previously, the addition of a green roof can also increase a building's energy performance. Please see Analysis II for an in depth calculation.

Materials and Resources Prerequisite (No Credit Given)

A building the size of 1099 New York Avenue requires a minimum of 275 sq. ft. to serve as a collection and storage area for all materials to be recycled on the project. These materials include paper, corrugated cardboard, glass, plastics, and metals. The Loading Dock area, which is located to the east of the building, is nearly 960 sq. ft. in area and is easily accessible from the public alley. This is currently where all waste materials on the project are being collected. As tenant construction begins and the construction area decreases, this area should still be able to provide adequate area for collecting and storing recyclable materials and still be functional as a loading dock.

Credit MR 2.1 & Credit MR 2.2 – Construction Waste Management

James G. Davis Construction Corporation currently has a developed waste management plan which they implement on all of their LEED projects. The provisions of this plan state that 75% of the waste material by weight generated on site will be diverted from disposal and recycled or salvaged for reuse.

Landfill diversion measures include targeting specific trades for their waste avoidance, donating reusable materials to charities such as Habitat for Humanity, and recycling those that cannot be salvaged or reused. Implementation is an effort on behalf of every member of the project team. Superintendents, subcontractors, and site workers are trained prior to start of construction. DAVIS superintendents are there to monitor waste on a daily basis, but subcontractors are required by their subcontract agreement to comply with all aspects of the plan.

Credit MR 4.1 – Recycled Content

Earning this credit requires that 10% (based on cost) of the total materials on the project consist of both post-consumer and pre-consumer recycled content. Post-consumer content is defined as waste material that can no longer be used for its intended purpose. Pre-consumer waste is defined as material diverted from the waste stream during the manufacturing process. Other materials such as scraps that are generated from a process in which they can be reused are excluded from this classification. The ratio of the 10% recycled content is post-consumer + ½ pre-consumer.

As mentioned before, the total cost of materials is assumed to be 40% of the total cost of construction for CSI Divisions 2-10 is $9,150,000. NewCem, a concrete additive used on the project, is considered to be post-consumer recycled content. Its cost makes up 1.17% of the material cost, leaving only another $800,000 in recycled material to be purchased as a replacement for use on the project.

Credit MR 6 – Certified Wood

Since this is a core and shell project and there is now wood framing on the project, this credit is not an expensive one to obtain. In order to meet the requirement for this credit, 50% of the wood (by value) used for the wood doors, furniture, and solid surfacing must by certified in accordance with the Forest Stewardship Council Principals and Criteria for wood building components. The FSC criterion guarantees that all wood products are harvested from well-managed forests around the country. This requirement can be easily written into construction specifications and subcontracts. All proof is the burden of the subcontractor.

Indoor Environmental Quality Prerequisite 1 (No Credit Given)

This credit requires that the building's ventilation system complies with the guidelines established in section 4-7 of ASHARE 62.1, Ventilation for Acceptable Indoor Air Quality. The code applies to all indoor or enclosed spaces that people may occupy regularly. There are two methods for determining the minimum ventilation rates: the Ventilation Rate Procedure, which is the most commonly used, and the Indoor Air Quality Procedure. As outlined in the code, the breathing zone outdoor airflow must be greater than or equal to the sum of the outdoor airflow required per person times the zone population, plus the outdoor air flow rate required per unit area times the zone floor area. The purpose of this prerequisite is to demonstrate that the building's delivered outdoor air or outdoor air intake is an adequate, healthy indoor environment.

Credit EQ 1 – Outdoor Air Delivery Monitoring

This credit can be obtained by locating CO_2 sensors in the return ducts at each level. These locations will confirm that the ventilation system is functioning properly. Typically, these sensors are set for an indoor concentration of 1000 ppm before alarming. Because the building is designed to be mechanically ventilated, an air flow monitoring station will have to be provided at the outdoor air intake. In doing so, the measured ventilation rate can be directly compared with the minimum rate required.

Credit EQ 3 – Construction Indoor Air Quality Management Plan

Davis Construction currently enforces a Construction Indoor Air Quality Management Plan on all of their LEED Projects. The plan restricts the use of permanently installed HVAC equipment until commissioning and keeps it protected from dust and odors that may be produced from construction activity. Only low-emitting materials as specified in Credits EQ 4.1, 4.2, 4.3, & 4.4 are to be are to be used within the building envelope. Work areas are to be well ventilated with outdoor air, and regular cleaning is scheduled to control contamination. Construction activities that require the use of highly polluting materials must be completed during off hours to ensure the health of other construction crews as well. The plan was previously used for a retail/office project at Potomac Yard in Arlington, Virginia (a LEED Gold project). It could easily be transferred to meet the core & shell requirements of 1099 New York Avenue.

Credit EQ 4.1, 4.2, 4.3, 4.4 – Low-Emitting Materials (3 Points)

The intent of these credits is to reduce the quantity of indoor air contaminants that are odorous, irritating, and/or harmful to the comfort and well-being of installers and applicants. This refers to all materials applied on-site within the weatherproofing system such as adhesives & sealants, paints & coatings, carpet systems and composite wood. These materials are still permitted on the project, but are limited to certain Volatile Organic Compound (VOC) levels. For instance, indoor carpet adhesives have a VOC density limit of 50 grams/liter (less water). Several manufacturers already make products that meet these specifications. Similar to using certified wood, this guideline can easily be written into construction specifications. It is already part of Tishman Speyer's contract agreement for future tenant construction.

<u>Credit EQ 5 – Indoor Chemical & Pollutant Source Control</u>

The purpose of this credit is to minimize the exposure of harmful pollutants to the building's occupants. On a core and shell project, the majority of this responsibility is placed on the tenants; however, there are several things the building developer can still to do help earn this credit. One way to do this is to provide adequate ventilation of hazardous gases and chemicals that may be present in the building. The primary location of these pollutants is in the below grade parking garage. In underground parking garages, the exhaust rate should be a minimum of 0.5 cfm/sq ft. Currently, the exhaust fans that are installed are set to perform at 24,000 cfm at each level. This is more than sufficient in a space of 15,800 sq ft. In order to complete this credit, it is recommended that exhaust fans be installed by the tenants in each work room that contains copy machines, printers and fax equipment. This equipment should also be located in rooms that have self closing doors to assure the toxins do not escape.

Air filtration is another area for pollutant control. In mechanically ventilated buildings, such as 1099 New York Avenue, all regularly occupied areas require air filtration media prior to occupancy that provides a Minimum Efficiency Reporting Value (MERV) of 13 or better. This rating refers to the average particle size (in ppm) that passes through the media. Filters with this rating are not specified for this project.

Dirt and particles from the outdoors that may be carried in on the feet of the building's occupants must also be monitored. Control of this requires the employment of permanent entryway systems of at least six feet in length in the primary direction of travel, which the building already has completed. However, within this entryway system there must also be grates, grilles, or slotted systems similar to the one depicted in **Figure 1.3** below that allow for cleaning underneath to collect dirt particles. Roll out mats may be substituted if they are maintained by a third party on a weekly basis.

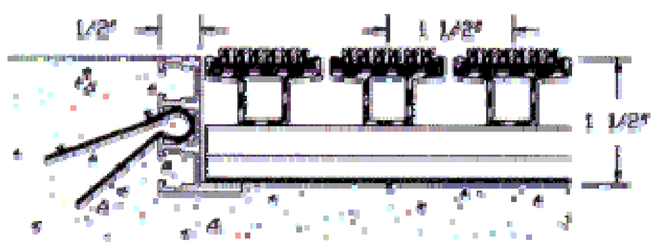


Figure 1.3 Depicts a standard entrance grate system. The tops of each strip can be finished with carpet, bristles, vinyl, or aluminum.

Conclusion & Recommendations

When implemented at the right phase of the design, building green is not a difficult feat to accomplish. Once the decision to go green has been made, the planning, design, and construction phases all become a team effort, but the responsibility of creating the guidelines to follow lies heavily on the owner of the project. The location for the project, the types of materials to be chosen, the energy performance requirements, and construction methods are all important factors in how the building will be rated. The previous analysis explained 26 areas where LEED credits could have been earned in an effort towards a Silver Rating for 1099 New York Avenue and set goals for all other future Tishman Speyer projects to obtain. Many of which were very simple alterations such as installing bicycle racks, others such as increasing energy efficiency required some engineering.

Cost is always a matter of discussion in the construction industry, especially with LEED projects since they typically have a higher initial cost than a non-LEED project. A recent study by Davis Langdon in 2007; however, proved that this statistic is more myth than fact. The study compared the overall cost of several different types of projects (academic, laboratory, library, and ambulatory care facilities) and found that the cost of going green is actually quite comparable if not less than a standard project. The collected data can be seen in the figures below.

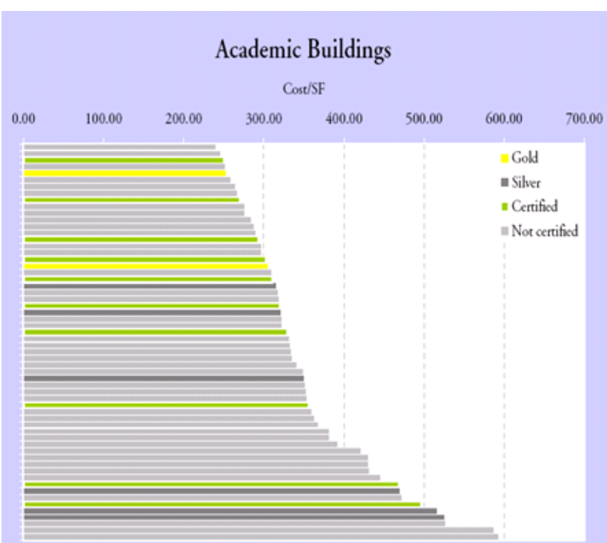


Figure 1.4a

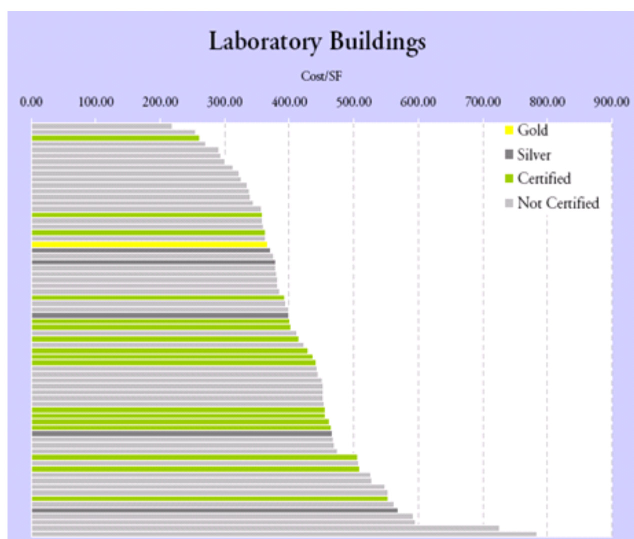


Figure 1.4b

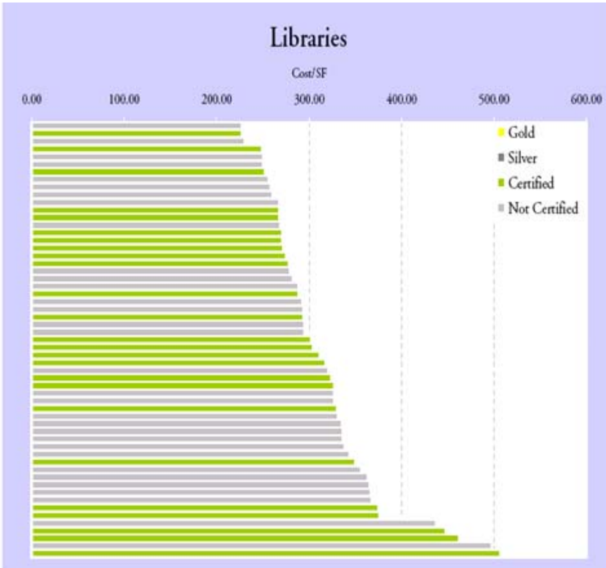


Figure 1.4c

Figure 1.4d

Figures 1.4a through 1.4d Depict the results of a cost comparison between LEED and non-LEED projects as determined by Davis Langdon in 2007

It was determined that there is a large variation of costs on both green and non-green projects. You can have an expensive LEED project and a lower costing one, but the same can be said for non-LEED projects. The total cost will be primarily controlled by the overall program for the building. The benefit of building green, however, is that a sustainable building will pay for itself through savings over time. Studies by the United States Green Building Council have shown that on average, 1%-2% of the construction cost is paid back per year in energy savings alone.

Tishman Speyer has already made movements in the right direction by setting a goal for all new projects to achieve a LEED Silver Rating. The next step is to develop the guidelines and course of action designers and contractors are to take in order to obtain that goal.

Analysis II – Energy Considerations for Green Roofs

Background

As seen from the previous analysis, many of the credits for sustainability can be obtained through the materials and methods of construction, but in order to achieve a LEED rating the building must also operate conservatively and efficiently. Because of a green roof's insulating properties, installing one can contribute to the more efficient operation of the building's HVAC system which translates to lower energy costs.

In the warm months, green roofs prevent the building from heating up inside, and in the winter months they aide the building in retaining heat. However, the degree of heat loss varies upon the amount of saturation retained within the drainage system. An increased amount of water retained will result in a decreased amount of heat loss experienced. As mentioned before, a green roof can hold several inches of water at a time. For the calculations in this analysis, an average depth of 1 ¼" of water will be assumed to be retained on the roof.

In order to achieve the LEED Silver Rating, 3 additional credits from those stated in Analysis I must be earned. The best scenario would be to earn these credits through optimizing the building's energy performance; however, it is unlikely that the addition of a green roof will provide the required 17.5% efficiency rate as compared to ASHRAE 90.1. Green roofs have been known to only reduce the cooling load by 25-50% on the floor directly below as compared to a typical built-up roof. Despite not receiving the additional credits through a green roof, the building will experience an enhanced performance. The following analysis will quantify the savings that installing a green roof on 1099 New York Avenue can provide.

The proposed green roof is to be a typical extensive system. Prospect Waterproofing, the project's roofing contractor, installs Garden Roof Assemblies as designed by American Hydrotech, Inc. The system is comprised of a concrete substrate, waterproofing membrane, rigid board insulation, a composite garden drainage layer, 3" of growing medium, and a top layer consisting of small plants such as grasses and mosses. A sample section can be seen in **Figure 2.1** below.

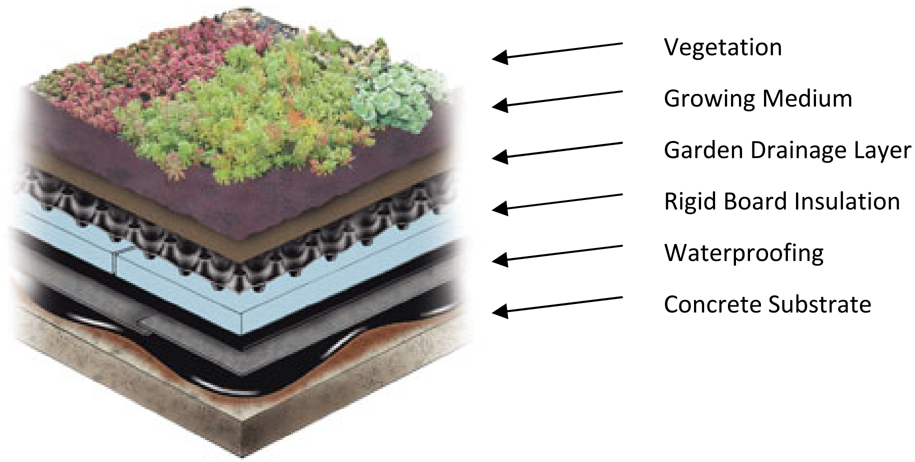


Figure 2.1 Typical extensive green roof assembly provided by American Hydrotech, Inc.

Problem

Green roofs can result in a significant increase in the cost of construction, but are often justified by the amount of energy savings they can provide. The enhancement of a building's performance from a green roof varies upon the composition of each layer of the roof system, the building's orientation, the area of coverage the green roof provides, and the ratio of that area to the area of occupied space inside the building. Considering that the thermal properties a green roof can provide vary from building to building, the realm of savings is not known until a building energy model can be constructed and compared against a baseline model.

The model is constructed through a series of equations using numbers from thermal properties of all the barriers between conditioned and non-conditioned inside areas, as well as the miscellaneous loads from lighting and office equipment. From these values the load demand and energy consumption can be calculated.

Objective

The objective of this analysis is to prove that the addition of over 8,000 sq ft of extensive green roof will contribute to the increase of the building's energy performance. To do this, an energy model of the existing project and a model of the project with the added green roof values will be constructed. The models will then be compared and a cost savings analysis will be performed. The expected outcome will be a reduced load on the eleventh floor of the building and a decrease in the overall energy consumption.

Analysis

The initial energy model was created using TRACE 700 energy modeling software by Trane in lieu of performing hand calculations. Below, **Table 2.1** shows the input values for the assumed office spaces and retail areas. The room sizes were predetermined by the project's Mechanical Engineer.

Room	Total Area (ft^2)	Roof (0.2135 Btu/h·ft^2·°F)	Wall 1 (0.0616 Btu/h·ft^2·°F)	Wall 2 (0.0616 Btu/h·ft^2·°F)	Wall 3 (0.0616 Btu/h·ft^2·°F)	Glass (0.29 Btu/h·ft^2·°F)	Floor (0.0908 Btu/h·ft^2·°F)
11th Floor							
Office 01	340	340	336			189	
Office 02	220	220	174	174		272	
Office 03	600	600	463			463	
Office 04	790	790	637			637	
Office 05	220	220	174	174		348	
Office 06	1,860	1,860	1,447			1,447	
Office 07	220	220	347	174	174	521	
Office 08	880	880	730			410	
Office 09	210	210	174	174		196	
Office 10	800	800	614			98	
Office 11	7,390	5,230					
Floors 02-10							
Office 01	340		336			189	
Office 02	220		174	174		272	
Office 03	600		463			463	
Office 04	790		637			637	
Office 05	220		174	174		348	
Office 06	1,860		1,447			1,447	
Office 07	450		174	347	174	521	
Office 08	880		730			410	
Office 09	210		174	174		196	
Office 10	800		614			98	
Office 11	7390						
Retail							
Retail 1	220		292			292	
Retail 2	220		240	258		498	
Retail 3	567		687			687	
Retail 4	230		283			283	
Retail 5	1,550						740
Retail 6	420		481			481	420
Retail 7	3,530						3,530
Retail 8	1,300		1,271			1,271	1,100

Table 2.1 displays the values entered into TRACE 700 for office area and thermal conductivity. Wall orientation was also entered into the calculations, but is not included in this table.

The following data output displayed in **Table 2.2** is the energy consumption summary for 1099 New York Avenue as intended in the original design.

Description	Electric Consumption (kWh)	Water Consumption (1000 gal)	Total Source Energy (kBtu/yr)
Primary Heating	101,605.4		10,404.4
Primary Cooling			
Cooling Compressor	278,840.5		28,553.3
Tower/Condenser	89,797	1,904.7	9,195.2
Cooling Accessories	8,760		897
Totals	**479,002.9**	**1,904.7**	**49,049.9**

Table 2.2 Energy Consumption Summary as designed for 1099 New York Avenue.

One average, the building was estimated to consume **479,002.9 kWh** and **1.9 million gallons** of water, totaling to **49,049.9 kBtu/yr**. Since green roofs are most efficient during the warm season, a monthly consumption breakdown from April through September has been provided in **Table 2.3** below.

Equipment	Apr	May	June	July	Aug	Sept	Total
Water-Cooled Chiller							
Electric (kWh)	21,106.3	26,409.8	29,487.3	32,811.9	30,499.3	26,128.0	166,443.0
Peak (kW)	46.0	57.4	65.7	68.8	65.1	58.3	361.3
Cooling Tower							
Electric (kWh)	7,669.0	9,507.3	9,200.6	9,507.2	9,507.3	9,200.6	54,592.0
Peak (kW)	12.8	12.8	12.8	12.8	12.8	12.8	76.8
Cooling Tower							
Make Up Water (1000 gal)	143.7	188.5	212.1	235.2	218.4	185.8	1,183.7
Peak (1000 gal/hr)	0.4	0.4	0.5	0.5	0.5	0.4	2.7
Control Panel							
Electric (kWh)	720.0	744.0	720.0	744.0	744.0	720.0	4,392.0
Peak (kW)	1.0	1.0	1.0	1.0	1.0	1.0	6.0
Heating							
Electric (kWh)	5,299.1	1,338.8	386.5	235.1	652.4	1,527.6	9,439.5
Peak (kW)	26.6	11.9	8.1	5.9	10.8	12.1	75.4

Table 2.3 Monthly Energy Consumption for April through September.

After the initial energy model was created, a second model was developed including the enhanced thermal properties of a green roof. To do this, a U factor had to be calculated for the extensive system assembly. The construction of the green roof consists of a 10" concrete slab with 2% reinforcement, neoprene flashing, 2" of rigid board insulation, a polyethylene drainage mat, 3" of growing medium, and a saturation level of 1.25". The measures of the materials' thermal resistance as stated in ASHRAE 90.1 are listed in the following table.

Material	Thickness (in)	R-Value ($h{\cdot}ft^2{\cdot}°F/Btu$)	U-Value $Btu/h{\cdot}ft^2{\cdot}°F$
Medium Density Concrete	10	5.68	0.18
Neoprene Flashing	0.25	0.06	16.7
Rigid Board Insulation	2	9.77	0.10
Polyethylene Drainage Mat	0.25	0.68	1.47
Growing Medium	3	9.144	0.12
Saturation	1.25	0.284	3.52
	Total	**25.6**	**0.04**

Table 2.4 R-Value Calculations for Extensive Green Roof System.

This new U-Value for the green roof of **0.04 $Btu/h{\cdot}ft^2{\cdot}°F$** should be compared to **0.2135 $Btu/h{\cdot}ft^2{\cdot}°F$** for the existing roof structure. **Tables 2.5 and 2.6** contain the energy consumption data for the building with the proposed green roof included.

Description	Electric Consumption (kWh)	Water Consumption (1000 gal)	Total Source Energy (kBtu/yr)
Primary Heating	95,785.6		9,808.5
Primary Cooling			
Cooling Compressor	274,133.8		28,071.4
Tower/Condenser	83,382.0	1,927.2	8,538.3
Cooling Accessories	8,760.0		897.0
Totals	**462,061.0**	**1,927.2**	**47,315.2**

Table 2.5 Energy Consumption Summary for building with the proposed green roof.

The addition of the green roof proved to reduce electricity consumption by **16,041.9 kWh** and although water consumption increased by **22,500 gallons**, the total source energy was reduced by **1,734.7 kBtu/yr**.

Equipment	Apr	May	June	July	Aug	Sept	Total
Water-Cooled Chiller							
Electric (kWh)	20,730.9	25,372.6	28,114.0	31,252.2	29,240.2	25,309.3	160,019.0
Peak (kW)	42.0	51.7	59.1	62.1	59.1	53.5	327.5
Cooling Tower							
Electric (kWh)	7,167.0	8,697.0	8,416.4	8,697.0	8,697.0	8,416.4	50,090.8
Peak (kW)	11.7	11.7	11.7	11.7	11.7	11.7	70.2
Cooling Tower							
Make Up Water (1000 gal)	145.5	184.3	204.8	226.5	212.3	183.5	1156.9
Peak (1000 gal/hr)	0.3	0.4	0.4	0.5	0.4	0.4	2.4
Control Panel							
Electric (kWh)	145.5	184.3	204.8	226.5	212.3	183.5	1,156.9
Peak (kW)	1.0	1.0	1.0	1.0	1.0	1.0	6.0
Heating							
Electric (kWh)	5,006.8	1,288.4	368.1	216.4	621.9	1,482.3	8,983.9
Peak (kW)	24.4	11.6	5.8	5.7	7.5	12.1	67.1

Table 2.6 Monthly Energy Consumption for May through September with proposed green roof.

A comparison of the source energy consumption and the observed savings can be seen in **Table 2.7** below.

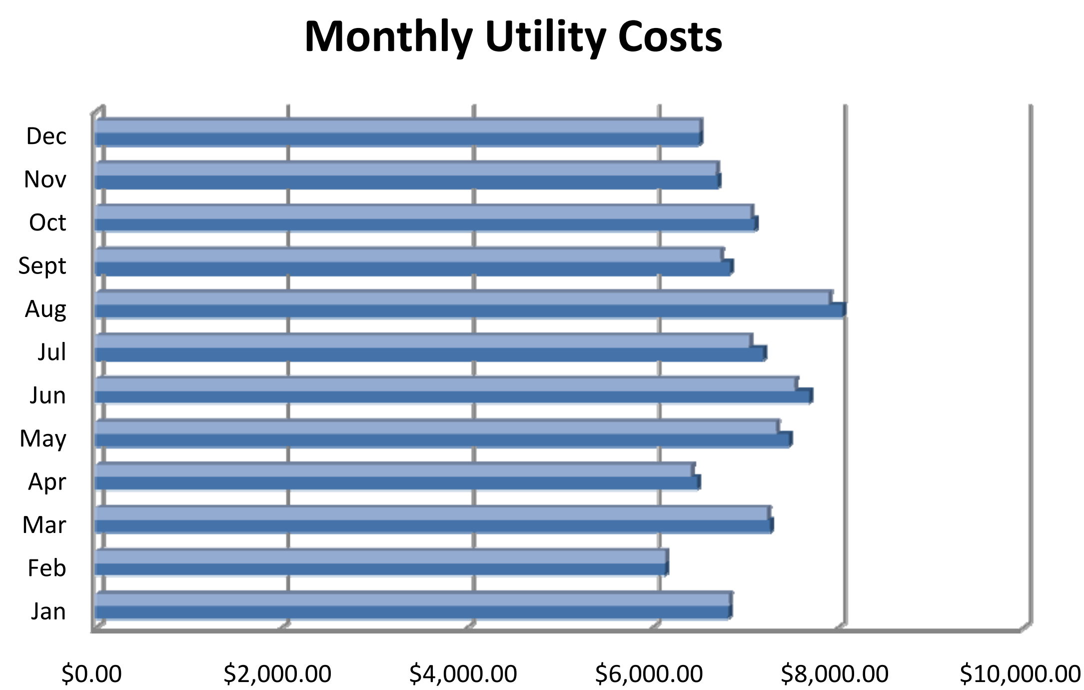
Total Source Energy as Designed (kBtu/yr)	Total Source Energy w/ Green Roof (kBtu/yr)	Estimated Savings
49,049.9	47,315.2	3.54%

Table 2.7 Estimated source energy savings.

After both calculations were performed, a total source energy savings on an annual basis of **3.54%** was observed. This is largely due to the decrease in electricity consumption. Assuming an average cost of $0.1214 per kilowatt-hour and $2.14 per 1000 gallons of water for commercial buildings in the District of Columbia, a cost comparison chart was formulated to analyze the annual savings in utility costs. (See **Chart 2.1** below.)

The total estimated cost for the annual electricity and water consumption as designed is **$84,217** whereas the estimated cost with the green roof is **$83,372**. The result is a savings of **$845** or **1%** per year.

The savings in energy consumption is a direct effect from the green roof reducing heat loss and building envelope cooling loads. The enhanced insulation from the green roof transmits 10,000 Btu less per hour than the conventional roofing system. Additionally, on the eleventh floor return airflow was decreased by 1,000 cfm and the plenum sensible load was reduced by 150,000 Btu/h.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Green Roof	$6,825.	$6,132.	$7,237.	$6,414.	$7,333.	$7,530.	$7,039.	$7,899.	$6,730.	$7,050.	$6,680.	$6,500.
Existing	$6,815.	$6,131.	$7,268.	$6,482.	$7,465.	$7,685.	$7,194.	$8,050.	$6,830.	$7,096.	$6,703.	$6,499.

Chart 2.1 visualizes the comparison of monthly utility costs between the two roof systems.

Cost Impact

The built-up roof as designed for the project costs an estimated $275,000. Prospect Waterproofing has estimated that the proposed green roof system will cost an additional $10 per sq ft resulting in a total increase of $82,700 (30%) to $357,700 overall for the roof. The energy cost savings experienced by the addition of a green roof only amounts to $845 per year.

The total savings over the life-cycle for the mechanical equipment (20 years) and the roof (50 years) is equal to $16,900 and $42,250 respectively. The costs savings summary can be seen in **Table 2.8** below. It would therefore take nearly 100 years for the initial cost of the green roof to be paid back from an energy standpoint. (Please note that this analysis is solely an investigation into the cost associated with energy savings at their present rate; therefore, neither the change in cost of the mechanical equipment nor the escalations in energy prices were measured for this analysis.)

Initial Cost Increase	Energy Savings (1 yr)	Energy Savings 20 yr (Life of Mechanical Equip.)	Energy Savings 50 yr (Life of Green Roof)
$82,700	$845	$16,900	$42,250

Table 2.8 Summary of the savings in cost of utilities for green roof installation

Conclusion & Recommendations

In other studies of green roofs, it has been found that the lower the ratio of roof area to building area, the less effective the installation of a green roof will be. In other words, green roofs do not work well on tall buildings. This is largely due the increased amount of area energy has to escape in other spaces in the building. The primary composition of the walls in this building is glass, a material with poor thermal properties. The majority of the energy savings from a green roof are generally experienced on the floor directly below the assembly. On 1099 New York Avenue, the 11th floor is only 9.1% of the total building area. That means that installing a green roof on this project is only able to optimize energy performance in 9.1% of the total building. As mentioned before in Analysis I, a green roof can only reduce 20-50% of energy consumption in this space.

The goal of this analysis was to evaluate the energy savings as the result of installing a green roof on the existing project at 1099 New York Avenue. It was found that a green roof could provide 3.54% efficiency, however the cost associated with savings was valued at only 1%. Despite the small measure of increased energy performance, a green roof system can still provide many other benefits as seen in Analysis I and it is therefore still recommended as a corrective course of action that should be taken for this project.

Analysis III – Structural Considerations for Green Roof

Background

Analyses I & II discussed the function of adding a green roof to the project from a sustainable and energy conservation perspective, however, there are other aspects of construction that need to be considered when an architectural feature is altered to this degree. Green roofs may decrease a building's peak load requirements for heating and cooling, but they can also add a sizable load to a roof structure. As discussed in Analysis I, the green roof selected to be installed is an Extensive System. Although designed to be light weight as compared to Intensive Systems, these green roofs can still contribute an additional 20-110 lbs/sq ft in dead load. In order to ensure that the roof structure can support such a load, a structural analysis of the current roof has to be done.

Problem

The green roof system selected is an estimated additional 19 lbs/sq ft in dry weight and 26 lbs/sq ft saturated on top of the self weight of the structure. Please refer to **Figure 2.1** in Analysis II for a typical section. The current lower roof level is designed to have public access and is scheduled to have concrete pavers installed as walkways. The additional load on top of the self weight in this area is 22 lbs/sq ft. In a post-tensioned slab such as this one, the additional 4 lbs/sq ft can be assumed as negligible. The area for concern is the roof above the mechanical penthouse. The current weight experienced by this roof system is only 8 lbs/sq ft.

Objective

To analyze the current penthouse roof structure and make the necessary calculations to appropriately size a slab for the additional load to be experienced.

Analysis

In order to earn credit SS 7.2, the green roof must cover 50% of 15,800 sq ft (the total roof area) which is equal to 7,900 sq ft. The proposed location for installation is on both the lower and mechanical penthouse roof structures which totals 8,270 sq ft. See **Figures 3.1 and 3.2** on the following page for the suggested layout.

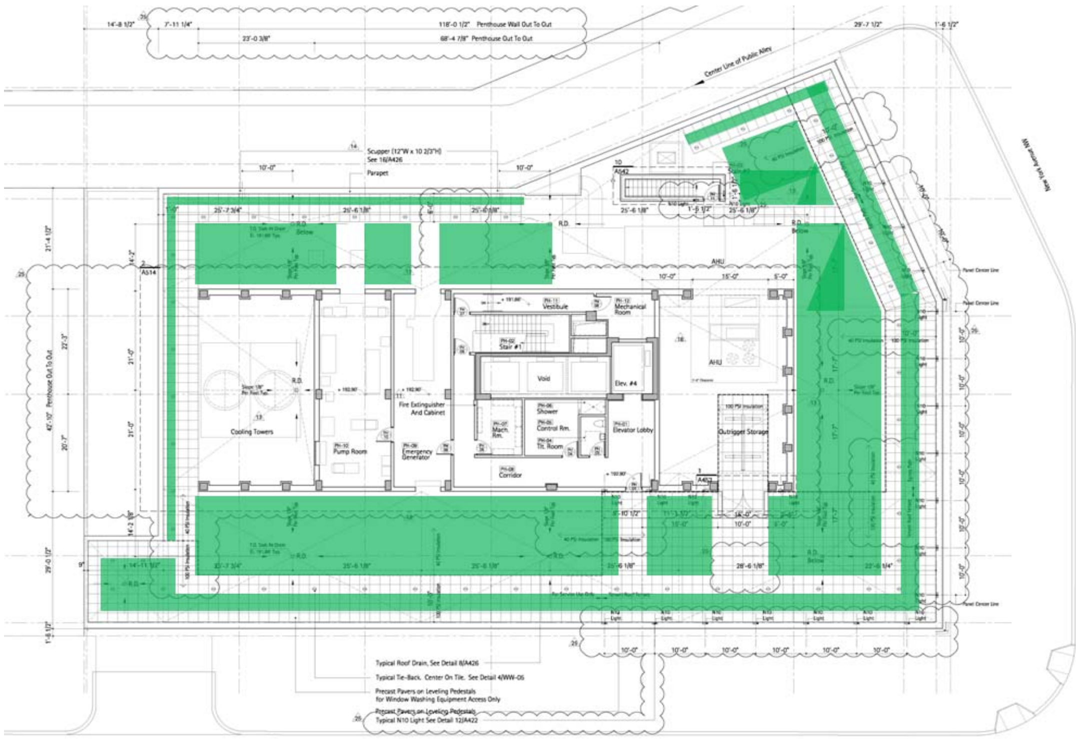


Figure 3.1 Suggested green roof layout for the lower roof. Total area is equal to **5,394 sq ft**. Please note that a through way for the window washing rig was considered.

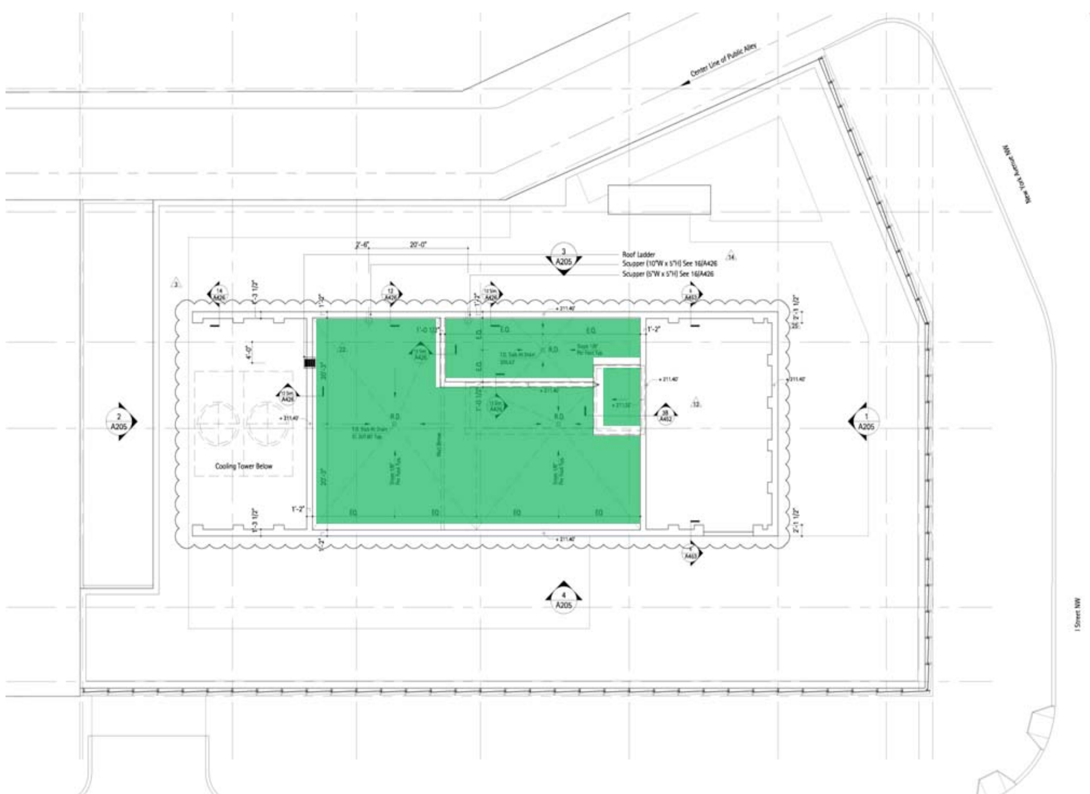


Figure 3.2 Suggested green roof layout for penthouse roof area. Total area is equal to **2,876 sq ft.**

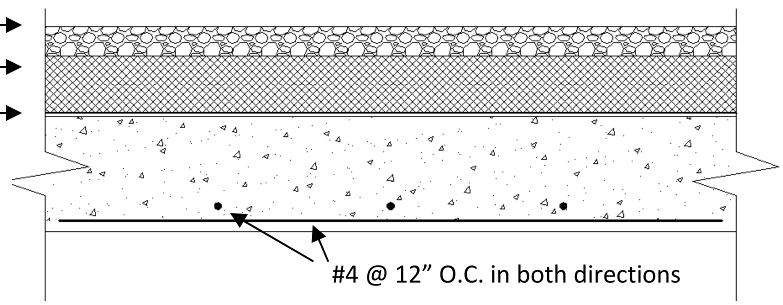
Current Penthouse Roof Slab:

8” Concrete Slab
Bottom Reinforcement: #4 @ 12” on center in both directions
F'_c = 4,000 psi

Loading (from ASCE7):

Live Load: 30 psf
Snow: 30 psf
Gravel Ballast: 5 psf
Polystyrene Foam Insulation: 1 psf
Filter Fabric: 1 psf
Waterproofing Membrane: 1 psf

Total Live Load = 30 psf
Total Dead Load = 38 psf



Current Penthouse Roof Section

Factored Loading: 1.2 D + 1.6 (L) + 0.5 (S) = 1.2 (8 psf) + 1.6 (30 psf) + 0.5 (30 psf) = 72.6 psf

Extensive Green Roof Loading:

Live Load: 30 psf
Snow Load: 30 psf
Extensive Green Roof System: 26 psf

Total Live Load = 30 psf
Total Dead Load = 56 psf

Factored Loading: 1.2 D + 1.6 (L) + 0.5 (S) = 1.2 (26 psf) + 1.6 (30 psf) + 0.5 (30 psf) = 94.2 psf

pcaSlab:

When the loading for the green roof system was entered into the pcaSlab program and applied to the current roofing system, the program reported that the current reinforcement was not sufficient. In order to be structurally sound in an 8” slab, the size of the reinforcement would have to be increased.

After reconfiguring the reinforcement in pcaSlab to accommodate the additional weight from the green roof, it was determined that the preferred alternative system would still be an 8" concrete slab, but #5 reinforcement at 12" on center would be required. Although #4 reinforcement could still have been utilized, the spacing and number of bars that would be required varied greatly from section to section. The #5 reinforcement was chosen because it proved to be more economical and logical from a construction management point of view. Since their spacing was more uniform and fewer bars were required, the schedule and budget would be better maintained.

Hand Calculations for Verification:

To begin, I followed the direct design method for two-way slabs. (Full design calculations can be viewed in **Appendix D**)

Step 1

- Uniform load determined to be 214 psf (includes self weight of 8" normal weight concrete slab)
- Minimum depth for two way slabs 4"(with drop panels) is less than the proposed 8"

Step 2

- Total static design moment was determined to be 79.3 ft-k in the short span direction
- Using the distribution factors for positive and negative moments from ACI 13.6.3, the following values were determined:

Interior Negative $M_u = 0.70M_o = 55.5$ ft-k
Exterior Negative $M_u = 0.26M_o = 20.6$ ft-k
Positive $M_u = 0.52\ M_o = 41.2$ ft-k

- Total static design moment was determined to be 95.9 ft-k in the long span direction
- Using the distribution factors for positive and negative moments from ACI 13.6.3, the following values were determined:

Interior Negative $M_u = 0.70M_o = 67.1$ ft-k
Exterior Negative $M_u = 0.26M_o = 24.9$ ft-k
Positive $M_u = 0.52M_o = 49.9$ ft-k

Step 3

- The column strip width was determined to be 7 ft
- According to ACI 13.6.4, the column strip supports 75% of the interior negative moment, 75% of the exterior negative moment, and 60% of the positive moment

	Column Strip Slab Moment (ft-k)	Middle Strip Slab Moment (ft-k)
Short Span		
Interior Negative	41.6	13.9
Exterior Negative	15.5	5.1
Positive	24.7	16.5
Long Span		
Interior Negative	50.3	16.8
Exterior Negative	18.7	6.2
Positive	29.9	20

Table 3.1 Displays the moment distribution over the slab area.

Step 4

- The minimum effective depth was determined to be 2.2" in the short direction and 2.53" in the long direction. For the slab, d = 6" & 7" will be used respectively
- For shrinkage and temperature, the minimum area of steel required was calculated to be 0.173 in^2/ft^2
- In the Long Span, ρ_{min} = 0.0021
- In the Short Span, ρ_{min} = 0.0024

Step 5

See **Table 3.2** below for design of slab reinforcement

	Location	M_u (ft-k)	b (in)	d (in)	M_u x 12/b (ft-k)	ρ	A_s (in^2)	Bars
Long Span								
(2) Half Col. Strip	Int. Neg.	50.3	84	7	7.2	0.0025	0.236	#5@12" O.C.
	Ext. Neg.	18.7	84	7	2.67	0.0021	0.200	#5@12" O.C.
	Positive	29.9	84	7	4.3	0.0021	0.200	#5@12" O.C.
Mid. Strip	Int. Neg.	16.8	132	7	1.5	0.0021	0.200	#5@12" O.C.
	Ext. Neg.	6.2	132	7	0.6	0.0021	0.200	#5@12" O.C.
	Positive	20	132	7	1.8	0.0021	0.200	#5@12" O.C.
Short Span								
Ext. Col. Strip	Negative	15.5	42	6	4.4	0.0024	0.230	#5@12" O.C.
	Positive	24.7	42	6	7.1	0.0029	0.280	#5@12" O.C.
Middle	Negative	13.9	84	6	2.0	0.0024	0.230	#5@12" O.C.
	Positive	16.5	84	6	2.4	0.0024	0.230	#5@12" O.C.
Int. Col. Strip	Negative	41.6	42	6	11.9	0.0050	0.480	#5@7 ½ " O.C.
	Positive	324.7	42	6	7.1	0.0029	0.280	#5@12" O.C.

Table 3.2 Displays the reinforcement design for the slab.

Step 6

- The nominal shear strength for the slab was calculated to be ϕV_c = 111.4 kips
- The factored shear for the slab was calculated based on the tributary area of each column to be V_u = 53.9 kips, which is well below the maximum 111.4 kips. Therefore no additional reinforcement, including drop panels, for punching shear is required.

Step 7

- The design strength for axial loading about the 24”x14” columns was determined to be ϕP_n = 898.6 kips and ϕM_n = 247 ft-kips.
- The factored axial loading experienced at each interior column is P_u = 53.9 kips which is well below the maximum 898.6 kips.
- The maximum factored moment experienced at each interior column is M_u = 95.9 ft-kips. Therefore the existing column is sufficient for carrying the additional load from the green roof system.

Cost Comparison

- As mentioned in Analysis II, the extensive green roof system to be installed will be an additional $10 per sq ft (including labor) according to Prospect Waterproofing, the current roofing contractor on the project. This will increase in the overall roof cost of $275,000 by **$82,700** (30% increase).
- The additional reinforcement required to support the green roof will add an additional 2,000 lbs to the slab and an additional **$1000.**
- Removing the drop panels will save 10 CY of concrete and 2,000 lbs of reinforcement. This would save **$2,100** in material cost and **$300** in labor.
- The total increase in cost would be **$81,300.**

The cost comparison can be visualized in **Table 3.3** below.

Description	Cost
Original Roof Cost	$275,000
Additional Cost for Green Roof Material	$82,700
Increased Reinforcement	$1,000
Concrete Material Savings	($2,100)
Concrete Labor Savings (1 day)	($300)
Total Additional Cost	**$356,300**

Table 3.3 Summary of the savings in cost of materials for green roof installation.

Schedule Impact

- The installation of a green roof would require an additional 2-3 days beyond the planned 35 days. Considering the roofing installation is not on the critical path nor is it a precursor to any other construction activity, no delays should be expected.
- Currently the concrete carpenters can install formwork at an estimated 69 sq ft/hr. With the drop heads no loner being required, there is over 500 sq ft of formwork that no longer needs to be installed. This can save nearly one work day.

Conclusion & Recommendations

To continue from the discussion from Analysis II, a green roof can add considerably to the cost of the project. It was previously determined that it would take 100 years for the building to payback the added initial cost of $82,700. The calculations in this analysis proved that the overall cost of adding the green roof could be reduced by an amount of $1,400 to $81,300 considering the excess of material and labor that was originally designed for the existing project.

If a green roof were to be installed on the project, a redesign of the structural system would prove to be economically feasible. To further analyze the cost, the installation of the traditional roofing system would require a reinvestment of $284,000 after 20-25 years for repairs/replacement assuming a rate of $3.50/sq ft for demolition and $14.50/sq ft for the new built-up roof and related flashings. An extensive green roof would not require this degree of maintenance for 50 years. The cost comparison is illustrated in **Chart 3.1** below. Including the annual savings of $845 from Analysis II, the green roof system will pay for itself after a period of 20 years when the built-up roof would have to be replaced. At this point the existing roof will have cost $559,000 and the proposed green roof will have cost $339,400. (Please note, 20 years is the extent of the warranty on the roofing system and it is being considered as a conservative estimate for the life span.)

To remain consistent with Analysis I & II, installing a green roof would be a sensible solution to achieving sustainability for 1099 New York Avenue.

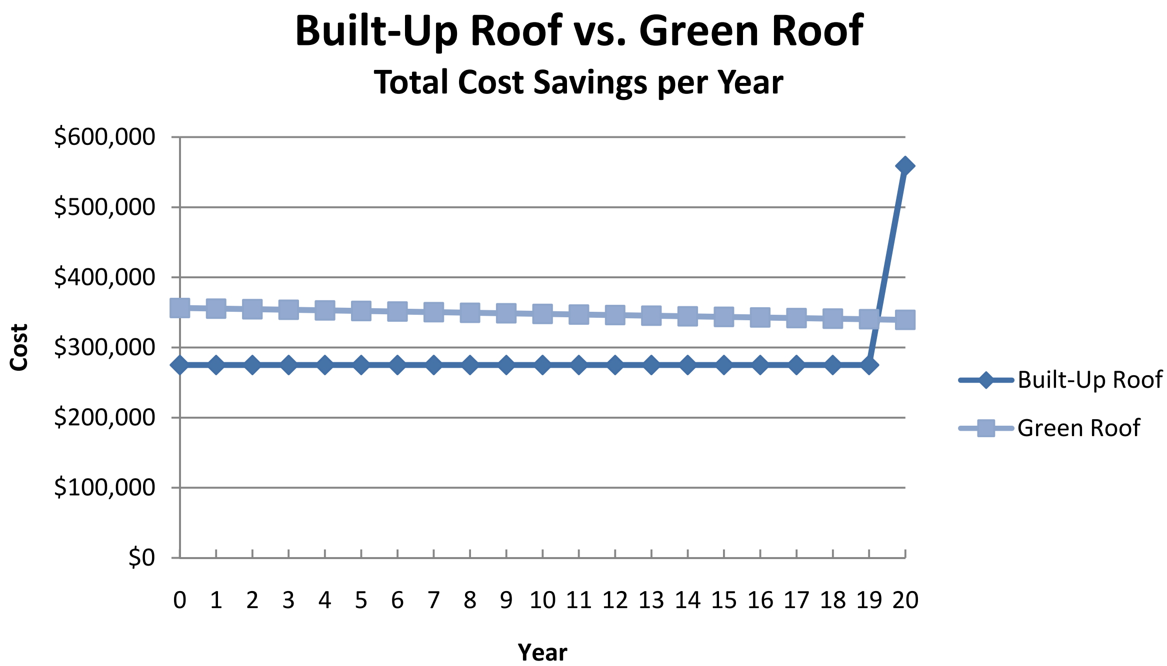


Chart 3.1 Displays the cost savings per year for a built-up roof versus a green roof. The green roof will pay itself back between year 19 and 20.

Analysis IV – Mapping & Testing MEP Coordination

Background

Building green is not just achieved though the methods of construction or the manner in which a building "performs", it is also a state of mind. The idea of sustainability follows the theory of Lean Thinking, a theory that is based upon the removal of waste from production and the creation of value. These methods were pioneered in Japan by Toyota after World War II. They can be simply defined as the combination of craft production in which skilled workers produce custom products and mass production which uses narrowly skilled workers to produced a standardized product. The result is an assembly of team members that possess a variety of skills working at all levels of an organization to produce large volumes in wide varieties.

Lean thinking promotes five basic principles that are fundamental to the elimination of waste.

1. Specify what does and does not create value from the customer's perspective and not from the perspective of the individual firms, functions and departments.
2. Identify all the steps necessary to design, order, and produce the products across the whole value stream to highlight non-value adding waste.
3. Make those actions that create value flow without interruption, detours, backflow, waiting or scrap.
4. Only make what is pulled by the customer.
5. Strive for perfection by continually removing successive layers of waste as they are uncovered.

The first step in the movement towards Lean Thinking involves understanding waste. The systematic attack of waste is an attack on the factors that underlie poor quality in production and managerial problems. The second step is establishing direction. Many lean initiatives are abandoned due to the lack of foresight. The next step is to understand the big picture of the process, all of its information and physical flows. Beyond this, each individual process is mapped, customers and suppliers become involved, and then the overall plan is checked against the intentions that were originally sought.

Although originally intended for the automotive industry, Lean Thinking can be applied to any manufacturing process, including those in construction. The primary focus of this analysis will be to identify the waste in the MEP Coordination process, determine what direction can be developed to remediate the waste, and assess the courses of action to be taken.

Problem

During core construction of the building it was discovered that although the MEP systems had been coordinated on the drawings, there was still difficulty with fitting all the components into the physical space. A redesign of the plenum space in the field was required to ensure that each system fit.

The same problem had been noticed in the lobby area as well. With the installation of the stone flooring and the ceiling system above, the available usable space was decreasing. This causes great concern because Tishman Speyer utilizes the lobby as one of the primary selling points for the building. Delays in construction result in potential client loss.

Objective

The objective of this analysis will be to map the 2D & 3D MEP Coordination process while analyzing Building Information Modeling (BIM) as a tool for efficiency. This will be done to determine the extent of the waste that can be removed from the process and the amount of productivity that can be added. Once a map of this operation has been developed, it will be tested using a 3D model of the MEP systems scheduled to be installed in the lobby. Each component will be constructed as it appears on the contract documents.

Analysis Part I

Understanding Waste

Waste can be defined as an activity that does not add value to a product or a service; the Japanese refer to it as "muda". In the Toyota Production System, seven different types of waste were identified. They are as followed:

1. **Overproduction –** producing too much or too soon, resulting in poor flow of information
2. **Defects –** frequent errors in paperwork, product quality problems, or poor delivery problems
3. **Unnecessary Inventory –** excessive storage and delay of information resulting in excessive cost and poor service
4. **Inappropriate Processing –** going about work processes using the wrong set of tools
5. **Excessive Transportation –** excessive movement of people, information or goods
6. **Waiting –** long periods of inactivity for people, information or products
7. **Unnecessary Motion –** poor workplace organization

The Lean Enterprise Research Center (LERC) at Cardiff Business School in England claims that when one thinks about waste, it is useful to define the three types of activities within an organization.

1. **Value Adding Activity –** an activity that, in the eyes of the customer, make a product or a service more valuable
2. **Non-Value Adding Activity –** an activity that, in the eyes of the customer, do not make a product or a service more valuable and are not necessary even under present circumstances
3. **Necessary Non-Value Adding Activity –** an activity that, in the eyes of the customer, do not make a product or a service more valuable but are necessary unless the existing supply process is radically changed

Through research, the LERC indentified the average ratio of activities to the total stream line in the informational flow environment, such as in the construction industry, as 1% value adding, 49% non-value adding, and 50% necessary but non-value adding.

The Dynamic System Model

Creating a model of a process can help one visualize a process and determine if the output is sufficient. If not, one can determine where the waste is developing and decide how to remediate the situation and optimize the overall performance. The dynamic system model was a theory developed by Milton Alexander in the 1970'2 as a simple method of mapping a dynamic system for a single process operation. The model consists of inputs for a processor to form outputs. Overseeing the process is a controller who regulates the flow of resources and inputs to the system.

The inputs are defined as the elements of a given system that are consumed or transformed during the process. Some inputs may be completely consumed or partially consumed and returned to input though maintenance. Outputs are the creation of the process, which is the method used to convert the input resources. The dynamic system model can be seen in **Figure 4.1** below. Ideas, thoughts or concepts do not function as inputs or outputs. They are merely feedback from which the controller uses to monitor the process. The controller not only regulates the flow of inputs, but determines how the process will meet its objectives and which rules it is to follow. The performance of the process relies ultimately on the controller's design and decision making; the controller is therefore the primary function that makes the model work. As it is in any process, the objective of Alexander's model is to maximize output while minimizing input and eliminating waste.

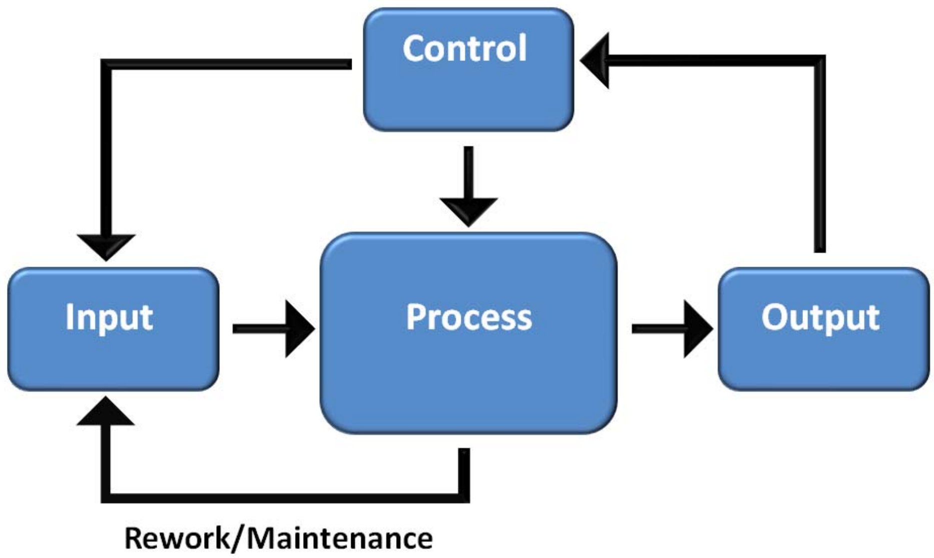


Figure 4.1 Shows the framework for Alexander's dynamic system model

Alexander's model is not designed for mapping an entire production like a construction project. The intent of creating such a model is strictly for detailing an individual component of a process, such as MEP Coordination, in order to gauge where productivity may be falling short.

The 2D Design Coordination Process

The traditional design coordination process begins after the preliminary design of the building systems are complete. As seen in **Figure 4.2** below, this occurs when roughly 60% of the design is complete. At this point the level of detail on the drawings is no more than the location and sizing of mechanical ductwork and piping. The electrical and fire protection systems have yet to be identified considering their installations tend to be more flexible. Coordination, of course, continues well through the design phase and into the construction phase.

Figure 4.2 Maps the components of the traditional design cycle for a project.

At the coordination meetings, various trades bring together their individual shop drawings, which have been developed from the contract documents and lay them on top of each other over a light table. Each trade then compares their individual design against the constraints that other building systems such as building structure, fire walls, equipment location, architectural features, and plenum space may present. Many of the early collisions are imposed by the specialty contractors when they take it upon themselves to optimize their respective systems by shortening branches, altering fittings, designing for efficient installation, etc. Once all the problems have been identified, the developed solutions are marked on the drawings. This process continues until coordination is complete, and all trades have signed each drawing to show their acceptance. The map of this process is illustrated in **Figure 4.3** below.

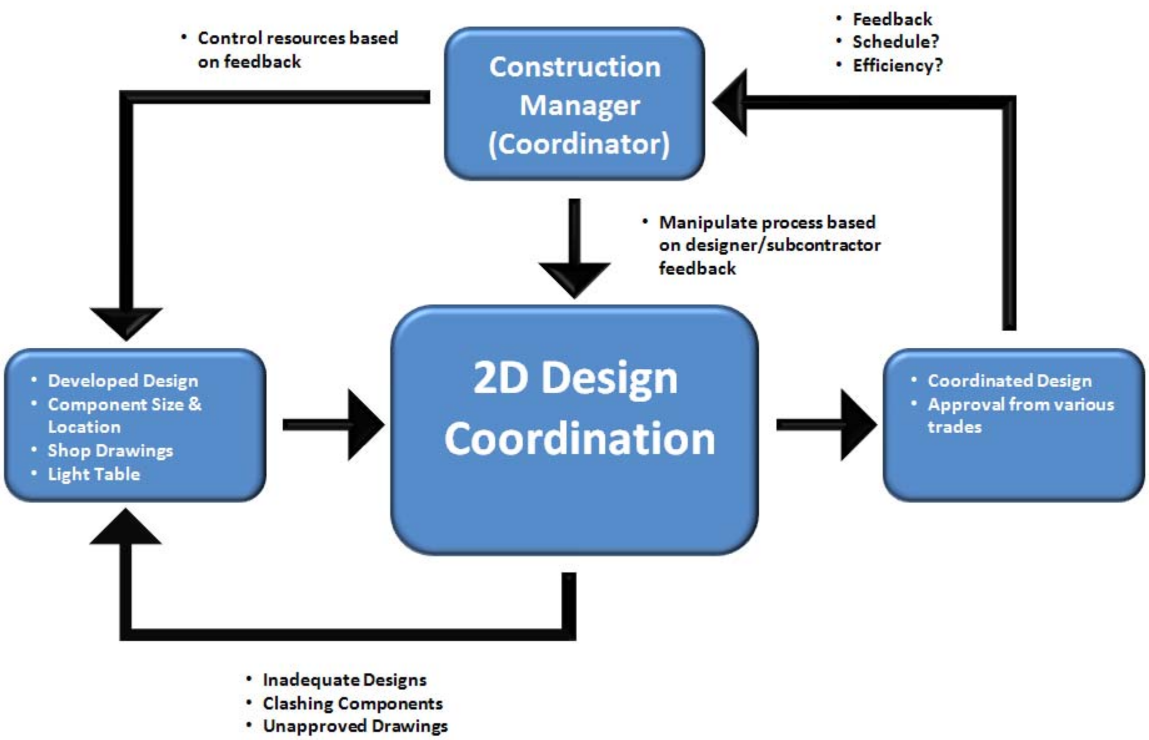


Figure 4.3 Displays the process map for 2D Design Coordination

This process can be classified as a non-value adding but necessary activity. It is very time-consuming, inefficient and often times leads to a less than desirable performance as many conflicts are still encountered and must be resolved in the field. Still, it is an integral part of combining different areas of the construction process. The majority of the waste from this process is found in the rework/maintenance loop between the inputs and the actual coordination process as seen in **Figure 4.4** below. The waste is developed from the inadequacies that characterize two dimensional drawings. Schematics and designs are revised several times because so many collisions are unnoticed. Even designs that are approved by all trades can result in poor performance when conflicts go undetected until they are assembled in the field.

Construction is a four dimensional process and can often times be difficult to portray or let alone understand when time and a spatial location are not accurately identified in the design. A building is not assembled with its components laid one on top of the other similar to the 2D coordination process, it is assembled to create a space in between and the most efficient way to construct that space is to visualize it in extreme detail prior to production.

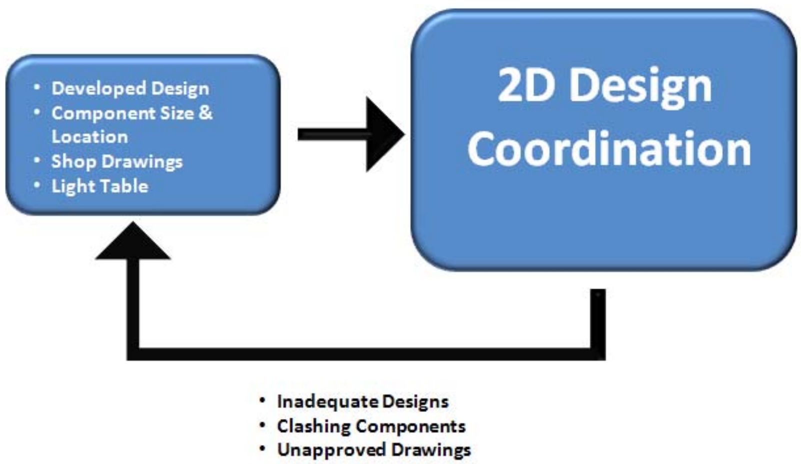


Figure 4.4 Diagrams the waste production cycle from the 2D Design Coordination Process

The 3D Design Coordination Process

The 3D Coordination Process functions similarly to the 2D Process. There is a difference, however, in the resources utilized. The construction manager still plays the same roll and coordination meetings are still held regularly, yet they are fewer and less frequent. Specialty contractors bring electronic models of their designs instead of paper shop drawings, and they are compared through a collision detection program as opposed to a light table. The intent of these tools is to improve the efficiency of the process by eliminating the rework loop associated with the traditional system.

Sheryl Staub-French of the University of British Columbia and Atul Khanzode of Stanford University described the optimal process based on challenges the encountered while studying the Camino Medical Group Project from January 2005 through April 2007.

1. Identify Potential Uses of the 3D Model
2. Identify the Modeling Requirements
3. Establish the Drawing Protocol
4. Establish a Conflict Resolution Process
5. Develop a Protocol for Addressing Design Questions
6. Develop Discipline-specific 3D Models
7. Integrate Discipline-specific 3D Models
8. Identify Conflicts between Components/Systems
9. Develop Solutions for the Conlficts Identified
10. Document Conflicts and Solutions

With improving technology, modeling programs that can optimize the development, routing, and connection of systems are continuously being developed to further aide in the planning, design, and inspection of the system components prior to construction. Utilizing this technology is part of what is known as Building Information Modeling. The CIC Research Group at the Pennsylvania State University defines as the process of designing, analyzing, integrating, and documenting a building's lifecycle by developing a virtual prototype of the building which includes a central database of information.

Barton Malow Company currently practices the 3D design coordination process out of their corporate headquarters in Michigan for healthcare facilities and industrial manufacturing projects. The process begins with a template model being created by the building's MEP engineering team. That template is then passed on to the respective trade to be further developed for fabrication. Coordination meetings begin as soon as primary duct and pipe arteries have been located and sized. The result is a fabrication level model. The process continues in the same manner until a conflict free design has been developed and approved.

Having the ability to visualize the building and its integral systems in a third dimension significantly enhances the coordination process. One of the major advantages is being able to make modifications and corrections to the model on site as opposed to over a week's time on paper. Barton Malow reports that an average of 90% of the errors are identified and solved right away. As a result, there are fewer Requests for Information (RFI's), less than 1% of the change orders on the project are design related, the schedule can be reduced by 30%, and cost savings can approach 20% (if all of the building is modeled). The ideal 3D design process can be seen incorporated with Staub-French and Khanzode's process in **Figures 4.5a & 4.5b** below.

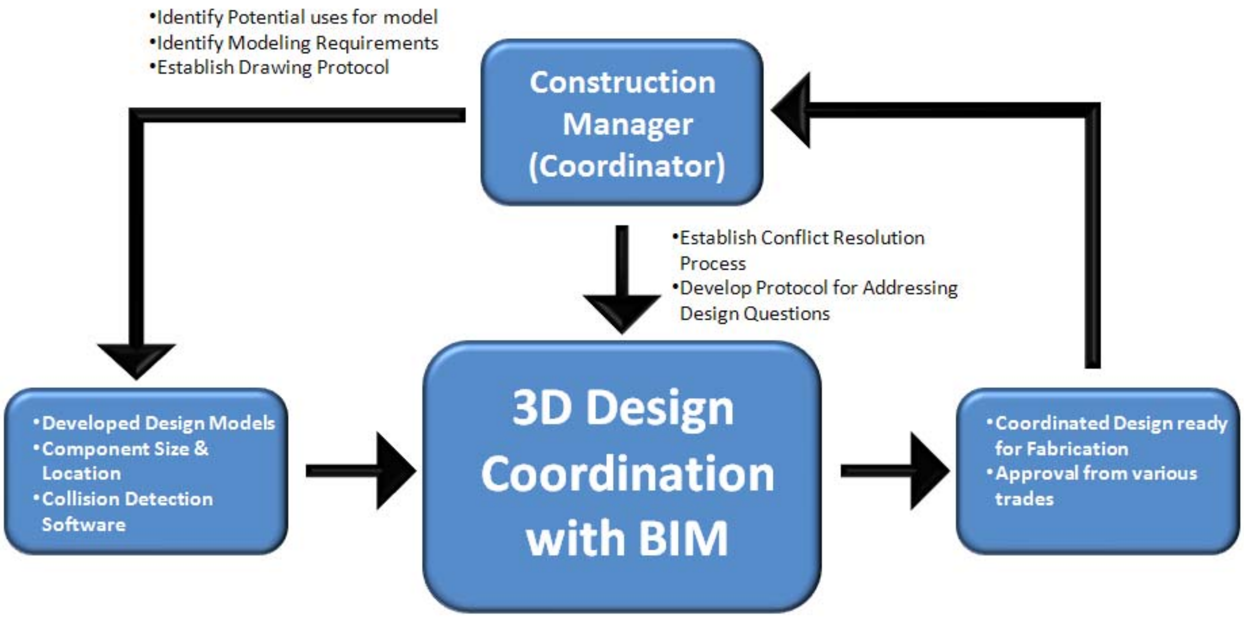


Figure 4.5a Shows the dynamic system model for the 3D design coordination incorporated with Staub-French and Khanzode's process. Note that the waste loop has been considered negligible.

Figure 4.5b Shows the details the 3D design coordination incorporated with Staub-French and Khanzode's process.

Analysis Part II

In order to test the effectiveness of the 3D Design Process, a model of the main lobby was constructed using Autodesk's Revit Desktop. Included were the mechanical, plumbing, electrical, and fire protection systems. The model was developed from the initial set of the Design Development drawings.

Step 1

- The architectural and structural components were loaded into Revit in order to create the lobby and plenum spaces. The ceiling is a 1 1/2" suspended painted drywall system. The finished floor to ceiling height is 14' – 7 ½" and the finished floor to the bottom of the slab is 16' – 6", thus creating a 1' - 9" plenum space.

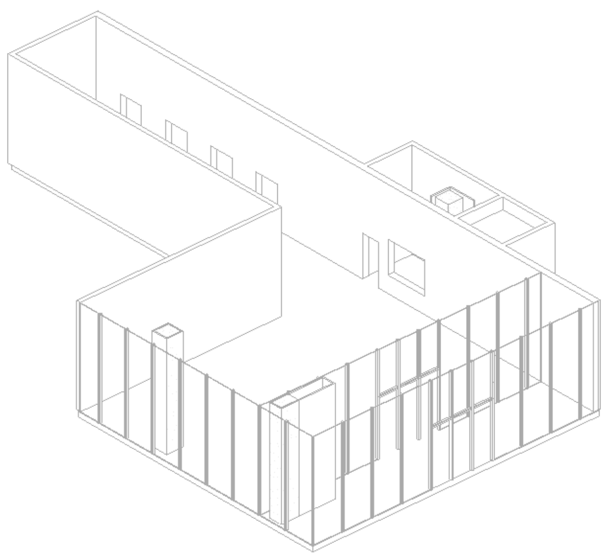


Figure 4.6 Model of the architectural features in the lobby

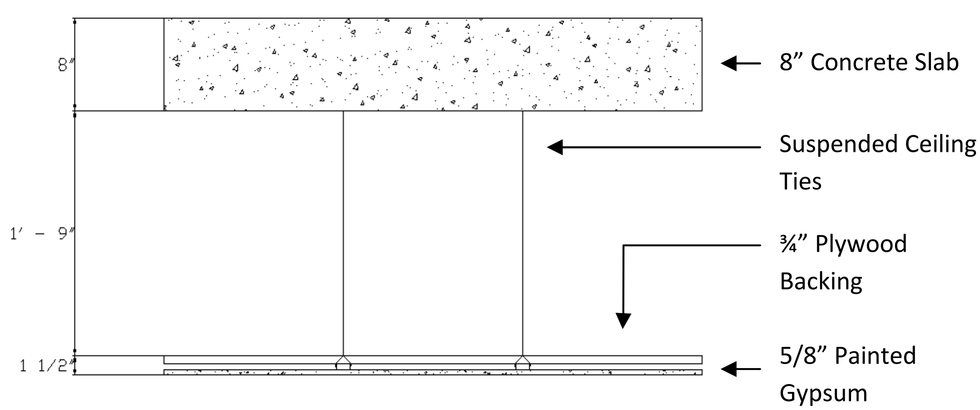


Figure 4.7 Section of the typical plenum space in the main lobby.

Step 2

- The mechanical ductwork and diffusers were added into the model. The duct was placed against the bottom of the slab and has a typical depth of 1' – 2". The diffusers were placed at the face of the exposed ceiling.

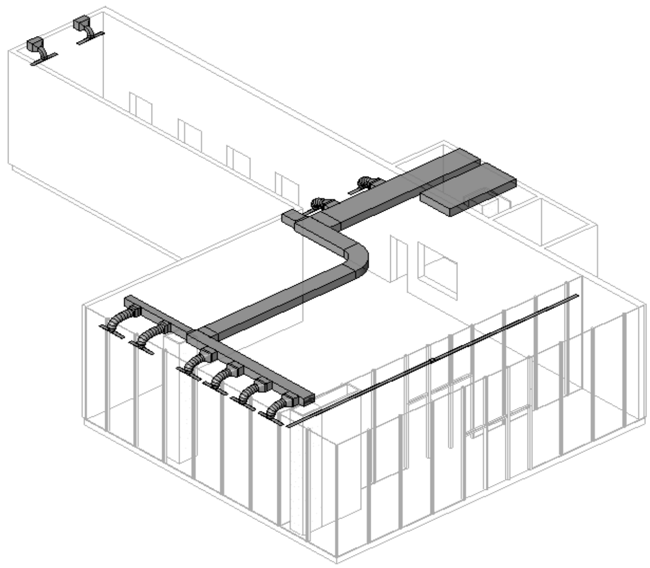


Figure 4.8 Lobby model with mechanical ductwork

Step 3

- The mechanical piping, fire protection and plumbing components were inserted. Pipe diameter ranged from 3" to 6" in diameter.

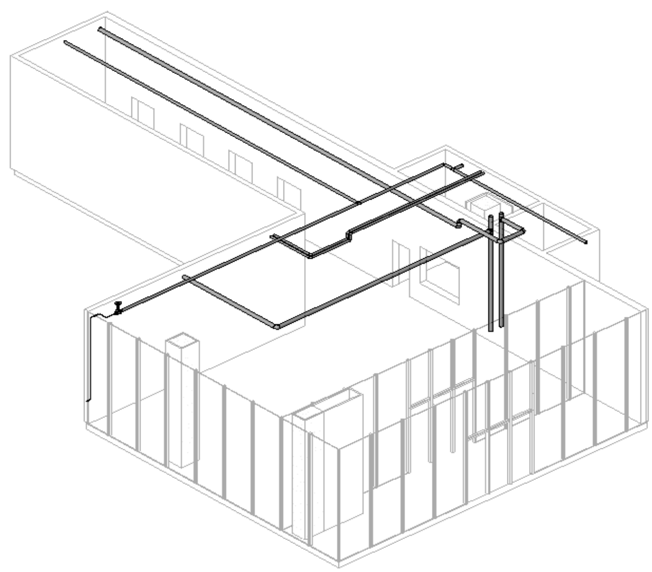


Figure 4.9 Lobby model with mechanical piping, stormwater, & fire protection plumbing systems installed.

Step 4

- The proposed light fixtures were inserted. Electrical conduit was excluded because it had not been sized or located at this point in the design.

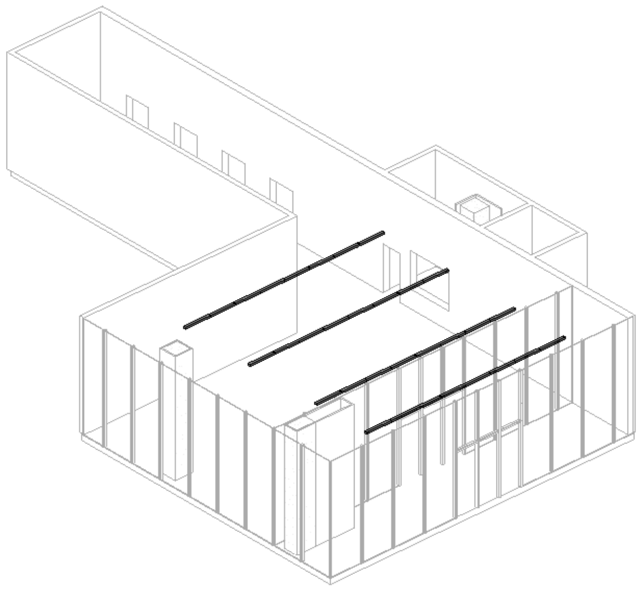


Figure 4.10 Lobby model with light fixtures

Step 5

- The model containing all building systems was uploaded into Navisworks Jetstream, a collision detection software program, and analyzed for inconsistencies.

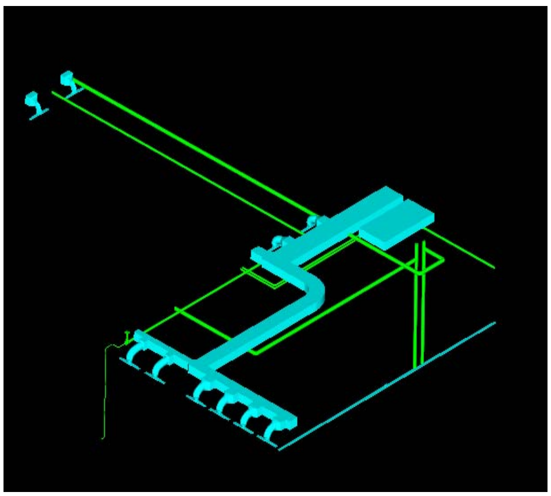


Figure 4.11 Caption of the lobby model as loaded into Navisworks Jetstream

- After running a collision test between the mechanical ductwork and plumbing systems, there was only conflict to be found. The fire protection pipe intersected with a duct line just above the space outside of the security office as highlighted below.

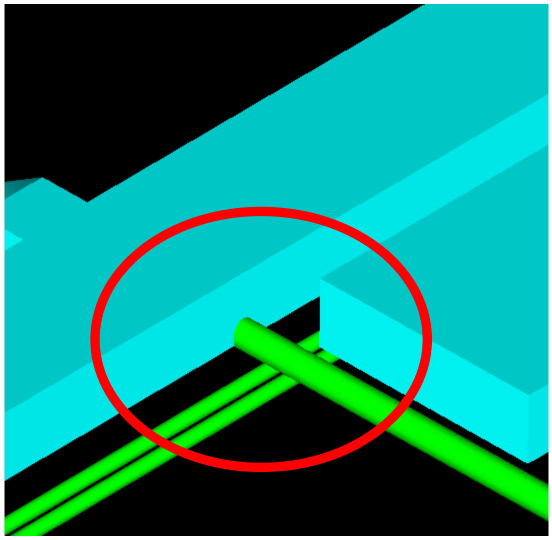


Figure 4.12 Caption of the intersection between the fire protection piping and the mechanical ductwork as determined through collision testing

<u>Why was there a collision?</u>

The area in question is highlighted in **Figure 4.13 below**. As mentioned before the available plenum space is 1' – 9". According to the design development drawings, a 14" deep duct, a 3" condenser water pipe, and a 4" cold water pipe are to pass through this area along with the 6" fire protection pipe segment. This is a total of 2' – 3" of material that needs to pass through a 1' – 9" section. The fire protection pipe must also be run under a 6" stormwater pipe in the middle of the lobby.

A clash like this could be missed in the coordination process and not discovered until after fabrication since it requires visualizing the system in a third dimension. At this stage of the design no elevation for system components is given on the drawings, so it must be determined by each of the individual trades. When the drawings are laid over top of each other, it appears as if there may be plenty of space, but if a section were to be drawn, the problem would be discovered. The amount of time it would take to develop a section for every area of the building would be quite inefficient considering that you would be drawing each component of the building two or three times. Constructing a model allows you to develop a plan and section simultaneously so the entire space can be seen.

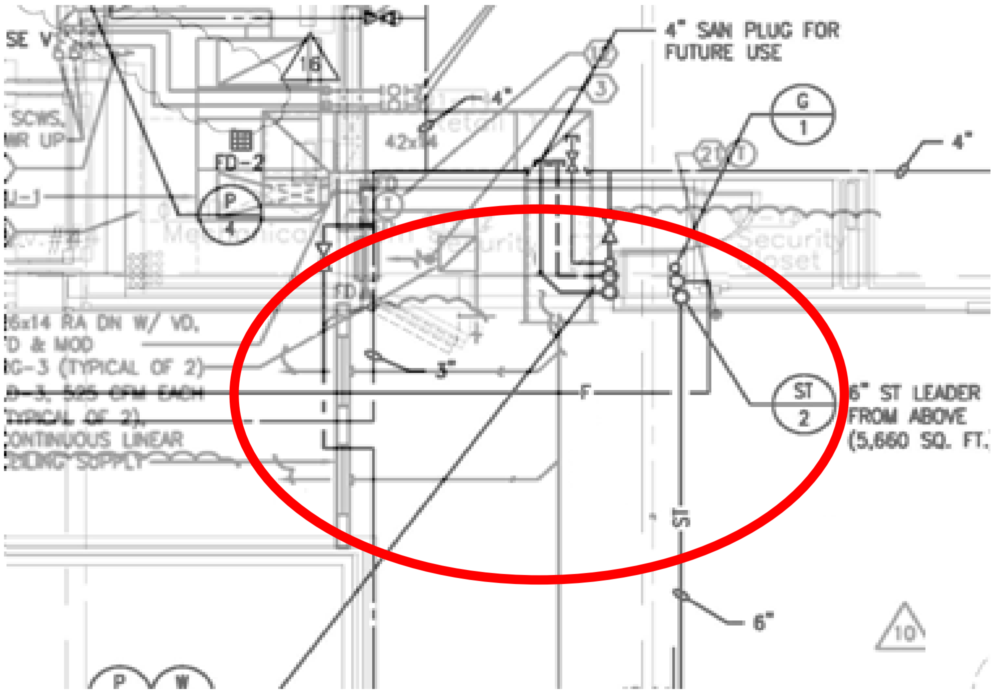


Figure 4.13 The area outside of the security office requires 2' – 7" of material to pass through 1' – 9" of space.

<u>How is the conflict resolved?</u>

The situation can be remediated by one of two methods.

1. The pipe or the ductwork can be resized to allow all materials to pass through
2. Change the location/elevation of the pipe or ductwork.

To spare the intensive calculations required to resize the pipe and ductwork, it was determined that relocating some of the elements would be a leaner approach. The 3" condenser water pipes were relocated to run between the two segments of ductwork and a series of 90˚ elbows was inserted into the 6" fire protection stretch so that it may pass the 6" stormwater pipe, the 1' – 2" deep ductwork, and the 4" cold water pipe collision free. The reconfiguration can be seen in **Figure 4.14** below.

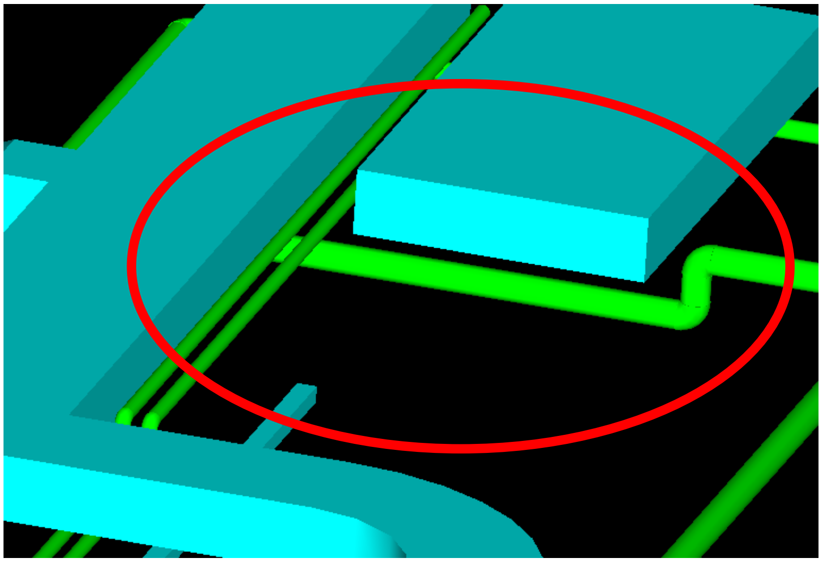


Figure 4.14 The suggested rerouting of the 6" fire protection pipe to accommodate the available plenum space.

In the 2D design coordination process, a correction such as this would require both the fire protection and mechanical contractor to leave the coordination meeting with unapproved drawings, reconcile the design flaw, issue another set of shop drawings and return to the following meeting to further investigate if the conflict has actually been resolved. The 3D design coordination process allows for the problem areas to be evaluated and solutions formed instantaneously. By following the process model, this collision specifically was remedied in a matter of minutes by a reconfiguration within the virtual model.

<u>Commentary on the 3D Design Process</u>

- Developing a three dimensional model from primitive construction documents is no simple task. Many of the dimensions and details required to make an accurate model are unavailable or difficult to translate. This becomes increasingly difficult when multiple trades are creating multiple models that need to be merged. The model created for this analysis was simple enough to create in one file.
- Revit MEP is too "user friendly". Many of the components that can be inserted into a model are standardized and can be difficult to customize. Routing pipe can also be a challenge as the majority of the connections and fittings are automated.
- Navisworks Jetstream's detection of collisions tends to be very elementary. The conflicts are not identified very well and can be difficult to locate in the model.

- It is important to develop a hierarchy for the order in which the different systems are to be installed and what precedence they take in location prior to the coordination meetings.
- Developing solutions should be a team effort. The coordinator should be able to accept suggestions just as well as he or she makes them. The suggestion of adding the elbows to the segment of fire protection piping may prove to be sufficient for the other systems but could be a more difficult installation for that contractor.
- Currently it appears as if the 3D design coordination process is more beneficial for a Design-Build delivery as opposed to Design-Bid-Build. It is beneficial to have the designers of the systems develop the models and pass them to the specialty contractors instead of relying on the trades to interpret the drawings themselves. To be more effective in the Design-Bid-Build method, the construction manager and major trades such as mechanical, electrical and plumbing onto the project during the design process.

Conclusion & Recommendations

The 3D Design Coordination has its flaws just as any other process may tend to have. With BIM still being established as a new technology, there is learning curve that has left many of the specialty contractors reluctant to change. The 3D process requires teamwork on all levels and cannot be performed efficiently if there is not equal involvement from all parties.

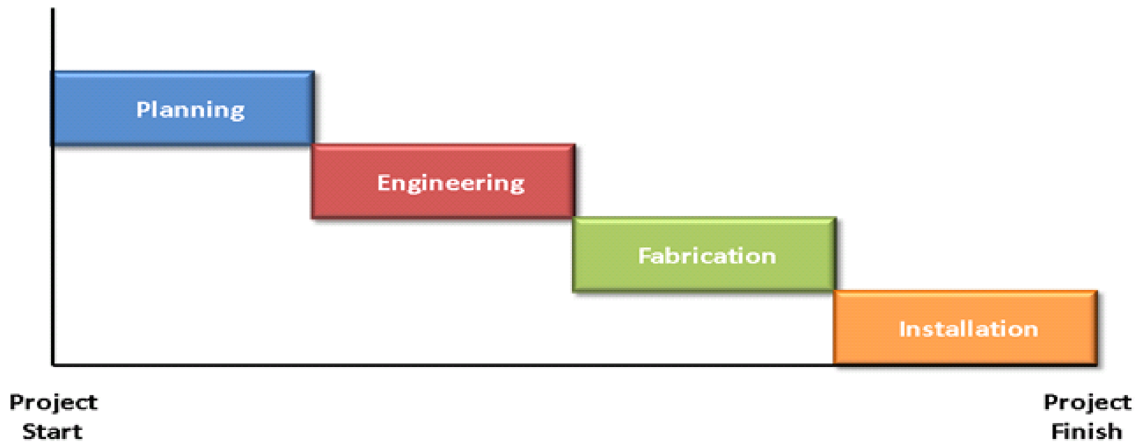
The process also requires a large initial investment in technology. Modeling and reviewing software, such as Revit Desktop and Navisworks Jetstream, as well as computers capable of supporting these programs are expensive.

To analyze the potential savings that utilizing BIM for MEP Coordination could provide, a series of five case studies on projects that used 3D Design Coordination were reviewed.

Project	Description	Estimated Increase in Productivity
A	General Motors Manufacturing Facility	30%
B	The Camino Medical Group Project	25%
C	Harborview Medical Center	50%
D	Alcoa World Alumina Plant	20%
E	NLA Federal Building	19%
	Average Productivity Increase	**28.8%**

Table 4.1 Summary of productivity increases as observed through case studies.

The estimate of a **28.8%** increase in productivity can be attributed to being able to identify most design conflicts prior to construction. This allows for fabrication to begin prior to the end of the coordination process, decreases the amount of rework in the field and provides a greater opportunity for pre-fabrication. When phases of a project can be intertwined in this, there is a margin of time savings that develops in the schedule.



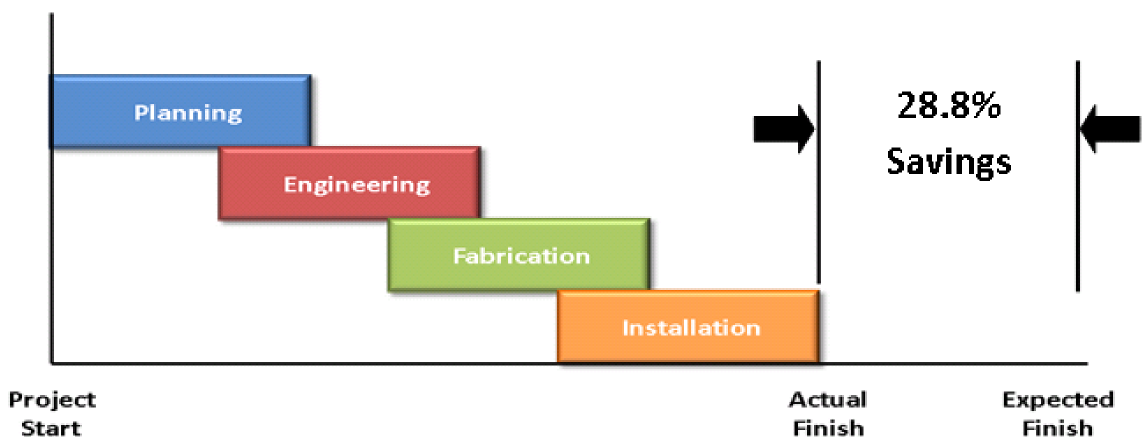


Figure 4.15 Models the savings in productivity as observed through the project case studies in Table 4.1

It should be noted that the majority of project case studies surveyed were based on either healthcare or manufacturing facilities which tend to be rather MEP intensive. 1099 New York Avenue is a core and shell office structure which means that the increase in productivity would be considerably less than what was projected in the figures shown above. As a conservative estimate, it shall be assumed that the increased productivity on core and shell projects shall be 60% of the value tabulated for the other programs. This percentage was chosen because a core and shell project does not require the construction of an entire building and would not involve quite as many MEP installations as a healthcare facility or manufacturing plant does. That would result in a total decrease of the project's duration by **17.3%** if the 3D design coordination process had been utilized on this project. If the beginning of the design phase remained 4/2/04, applying this 17.3% increase in productivity to the schedule summary would accelerate activity duration and provide a substantial completion date of 10/15/07. This date is just over 4 months prior to the originally intended substantial completion. Please note that this increase in productivity was only added to activities that would benefit from being modeled, those activities such as excavation, foundations, and installing the curtainwall panels were scheduled with their original durations intact. The comparison between the project schedules can be seen in **Appendix E**.

With such an increase in efficiency and accelerated schedule, it is recommended that Tishman Speyer begin incorporating Lean Processes such as 3D Design Coordination in their efforts towards sustainability.

Resources

1. "3D Building Information Models Add Value to Healthcare Projects." Turner Healthcare June-July 2006. 2 Apr. 2008 <http://www.turnerconstruction.com/healthcare/files_healthcare/Summer2006.pdf>.

2. Alexander, M. J. "Information Systems Analysis." Science Research Associates, Inc. (1974).

3. Balakrishnan, R. "The Toyota Production System: a Case Study of Creativity and Innovation in Automotive Engineering."

4. Coleman, Gabriel. "Hatch Utilizes EDI Technologies for Paperless Project Delivery." American Institute of Steel Construction.

5. "Core and Shell Development." Reference Guide. 2.0nd ed. Washington, D.C.: U.S. Green Building Council, 2006.

6. Hines, Peter, and David Taylor. Going Lean. Cardiff, UK: Lean Enterprise Research Center, 2000.

7. Korman, Thomas, and C. B. Tatum. "Coordinating Building Systems: Process and Knowledge." Journal of Architectural Engineering (2000): 116-121.

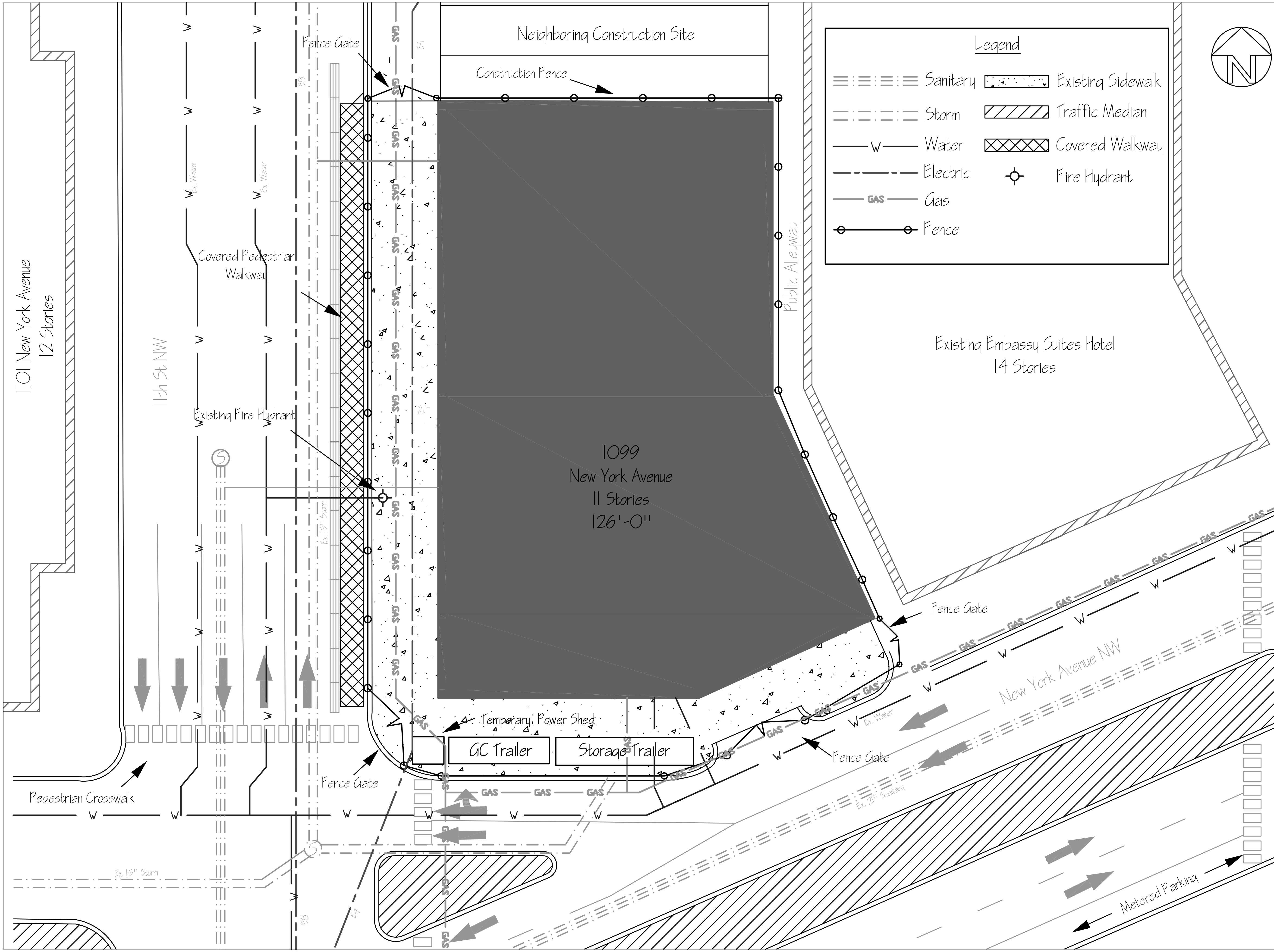
8. Matta, Charles. "The GSA's BIM Pilot Program." AIA TAP Knowledge Community. First Annual BIM Awards Competition. 2005. 2 Apr. 2008 <http://bim.arch.gatech.edu/data/reference/gsaBIM.pdf>.

9. Staub-French, Sheryl, and Anul Khanzode. "3D and 4D Modeling for Design and Construction Coordination: Issues and Lessons Learned." ITcon (2007): 381-408.

10. Tabesh, A. R., and Sheryl Staub-French. "Case Study of Constructability Reasoning in MEP Coordination." American Society of Civil Engineers (2004).

Appendix A

Project Site Plan



1099 New York Avenue
Washington, D.C.

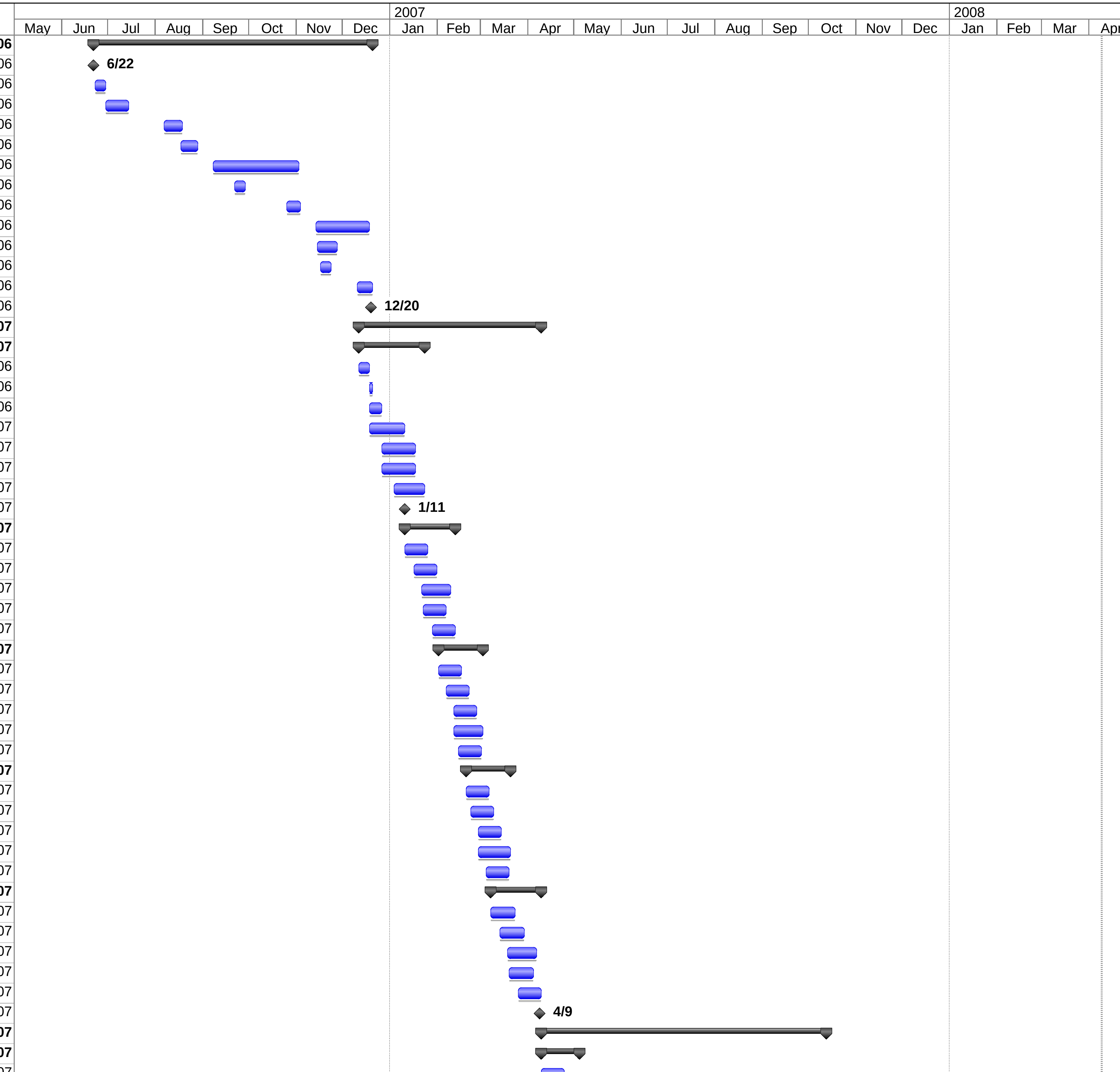
Existing Site Conditions
Drawn by: Will Cox
Date: October 5, 2007

1 of 1

Appendix B

Detailed Project Schedule

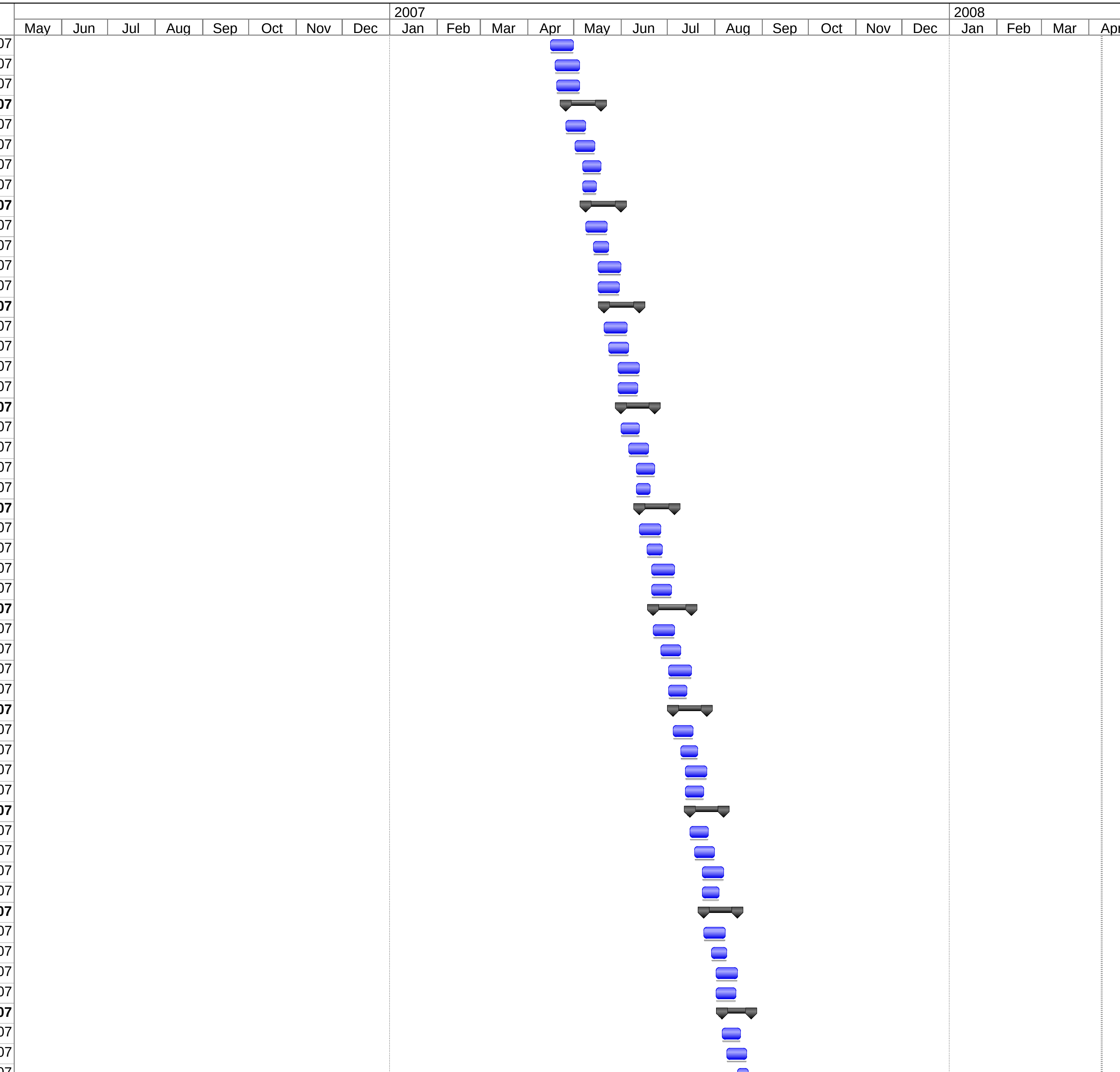
ID	Task Name	Duration	Start	Finish
1	**Excavation/Sheeting & Shoring**	**130 days**	**Thu 6/22/06**	**Wed 12/20/06**
2	Issue to Proceed	0 days	Thu 6/22/06	Thu 6/22/06
3	Mobilize Site	5 days	Fri 6/23/06	Thu 6/29/06
4	Demolish Existing Bldg. to Grade	11 days	Fri 6/30/06	Fri 7/14/06
5	Drive Soldier Beams	10 days	Mon 8/7/06	Fri 8/18/06
6	Cut to First tie level	7 days	Fri 8/18/06	Mon 8/28/06
7	Drill, grout & test tier ties	40 days	Fri 9/8/06	Thu 11/2/06
8	Cut to Middle Second Level	5 days	Fri 9/22/06	Thu 9/28/06
9	Install Temporary Shoring System at Northwest Corner	7 days	Thu 10/26/06	Fri 11/3/06
10	Install H1-H3 Rakers and Corner Bracing	25 days	Tue 11/14/06	Mon 12/18/06
11	Excavate/Pour Crane Pad	9 days	Wed 11/15/06	Mon 11/27/06
12	Move Ramp to Southwest Corner	5 days	Fri 11/17/06	Thu 11/23/06
13	Excavate to Subgrade	8 days	Mon 12/11/06	Wed 12/20/06
14	Excavation Complete	0 days	Wed 12/20/06	Wed 12/20/06
15	**Substructure**	**85 days**	**Tue 12/12/06**	**Mon 4/9/07**
16	**B4 Level**	**31 days**	**Tue 12/12/06**	**Tue 1/23/07**
17	Mobilization	5 days	Tue 12/12/06	Mon 12/18/06
18	Erect Tower Crane	2 days	Tue 12/19/06	Wed 12/20/06
19	Elevator Pit	6 days	Tue 12/19/06	Tue 12/26/06
20	Column/Wall Footings	17 days	Tue 12/19/06	Wed 1/10/07
21	Perimeter Walls/Columns to B3	16 days	Wed 12/27/06	Wed 1/17/07
22	Install Underground Plumbing	16 days	Wed 12/27/06	Wed 1/17/07
23	Slab on Grade	14 days	Thu 1/4/07	Tue 1/23/07
24	Tower Crane Operational	0 days	Thu 1/11/07	Thu 1/11/07
25	**B3 Level**	**23 days**	**Thu 1/11/07**	**Mon 2/12/07**
26	Frame, Reinforce, Cast, Cure, Strip Floor Pour #1	11 days	Thu 1/11/07	Thu 1/25/07
27	Frame, Reinforce, Cast, Cure, Strip Floor Pour #2	11 days	Wed 1/17/07	Wed 1/31/07
28	Walls/Columns to B2	15 days	Mon 1/22/07	Fri 2/9/07
29	Frame, Reinforce, Cast, Cure, Strip Floor Pour #3	11 days	Tue 1/23/07	Tue 2/6/07
30	Frame, Reinforce, Cast, Cure, Strip Floor Pour #4	11 days	Mon 1/29/07	Mon 2/12/07
31	**B2 Level**	**21 days**	**Fri 2/2/07**	**Fri 3/2/07**
32	Frame, Reinforce, Cast, Cure, Strip Floor Pour #1	11 days	Fri 2/2/07	Fri 2/16/07
33	Frame, Reinforce, Cast, Cure, Strip Floor Pour #2	11 days	Wed 2/7/07	Wed 2/21/07
34	Frame, Reinforce, Cast, Cure, Strip Floor Pour #3	11 days	Mon 2/12/07	Mon 2/26/07
35	Walls/Columns to B1	15 days	Mon 2/12/07	Fri 3/2/07
36	Frame, Reinforce, Cast, Cure, Strip Floor Pour #4	11 days	Thu 2/15/07	Thu 3/1/07
37	**B1 Level**	**21 days**	**Tue 2/20/07**	**Tue 3/20/07**
38	Frame, Reinforce, Cast, Cure, Strip Floor Pour #1	11 days	Tue 2/20/07	Tue 3/6/07
39	Frame, Reinforce, Cast, Cure, Strip Floor Pour #2	11 days	Fri 2/23/07	Fri 3/9/07
40	Frame, Reinforce, Cast, Cure, Strip Floor Pour #3	11 days	Wed 2/28/07	Wed 3/14/07
41	Walls/Columns to B1	15 days	Wed 2/28/07	Tue 3/20/07
42	Frame, Reinforce, Cast, Cure, Strip Floor Pour #4	11 days	Mon 3/5/07	Mon 3/19/07
43	**Ground Floor**	**23 days**	**Thu 3/8/07**	**Mon 4/9/07**
44	Frame, Reinforce, Cast, Cure, Strip Floor Pour #1	12 days	Thu 3/8/07	Fri 3/23/07
45	Frame, Reinforce, Cast, Cure, Strip Floor Pour #2	12 days	Wed 3/14/07	Thu 3/29/07
46	Columns/Interior Walls to 2nd Floor	15 days	Mon 3/19/07	Fri 4/6/07
47	Frame, Reinforce, Cast, Cure, Strip Floor Pour #3	12 days	Tue 3/20/07	Wed 4/4/07
48	Frame, Reinforce, Cast, Cure, Strip Floor Pour #4	11 days	Mon 3/26/07	Mon 4/9/07
49	Substructure Concrete Complete	0 days	Mon 4/9/07	Mon 4/9/07
50	**Superstructure**	**135 days**	**Tue 4/10/07**	**Fri 10/12/07**
51	**Second Floor**	**19 days**	**Tue 4/10/07**	**Fri 5/4/07**
52	Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #1	11 days	Tue 4/10/07	Tue 4/24/07



Project: 1099 New York Avenue
Date: Wed 4/9/08

Task		Progress		Summary		External Tasks		Deadline	
Split		Milestone		Project Summary		External Milestone			

ID		Task Name	Duration	Start	Finish
53		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #2	11 days	Mon 4/16/07	Mon 4/30/07
54		Columns/Interior Walls to 3rd Floor	12 days	Thu 4/19/07	Fri 5/4/07
55		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #3	11 days	Fri 4/20/07	Fri 5/4/07
56		**Third Floor**	**17 days**	**Thu 4/26/07**	**Fri 5/18/07**
57		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #1	9 days	Thu 4/26/07	Tue 5/8/07
58		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #2	9 days	Wed 5/2/07	Mon 5/14/07
59		Columns/Interior Walls to 4th Floor	10 days	Mon 5/7/07	Fri 5/18/07
60		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #3	7 days	Mon 5/7/07	Tue 5/15/07
61		**Fourth Floor**	**17 days**	**Wed 5/9/07**	**Thu 5/31/07**
62		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #1	10 days	Wed 5/9/07	Tue 5/22/07
63		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #2	8 days	Mon 5/14/07	Wed 5/23/07
64		Columns/Interior Walls to 5th Floor	11 days	Thu 5/17/07	Thu 5/31/07
65		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #3	10 days	Thu 5/17/07	Wed 5/30/07
66		**Fifth Floor**	**17 days**	**Mon 5/21/07**	**Tue 6/12/07**
67		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #1	11 days	Mon 5/21/07	Mon 6/4/07
68		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #2	9 days	Thu 5/24/07	Tue 6/5/07
69		Columns/Interior Walls to 6th Floor	10 days	Wed 5/30/07	Tue 6/12/07
70		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #3	9 days	Wed 5/30/07	Mon 6/11/07
71		**Sixth Floor**	**16 days**	**Fri 6/1/07**	**Fri 6/22/07**
72		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #1	8 days	Fri 6/1/07	Tue 6/12/07
73		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #2	9 days	Wed 6/6/07	Mon 6/18/07
74		Columns/Interior Walls to 7th Floor	10 days	Mon 6/11/07	Fri 6/22/07
75		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #3	7 days	Mon 6/11/07	Tue 6/19/07
76		**Seventh Floor**	**17 days**	**Wed 6/13/07**	**Thu 7/5/07**
77		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #1	10 days	Wed 6/13/07	Tue 6/26/07
78		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #2	8 days	Mon 6/18/07	Wed 6/27/07
79		Columns/Interior Walls to 8th Floor	11 days	Thu 6/21/07	Thu 7/5/07
80		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #3	9 days	Thu 6/21/07	Tue 7/3/07
81		**Eighth Floor**	**17 days**	**Fri 6/22/07**	**Mon 7/16/07**
82		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #1	10 days	Fri 6/22/07	Thu 7/5/07
83		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #2	9 days	Wed 6/27/07	Mon 7/9/07
84		Columns/Interior Walls to 9th Floor	11 days	Mon 7/2/07	Mon 7/16/07
85		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #3	10 days	Mon 7/2/07	Fri 7/13/07
86		**Ninth Floor**	**16 days**	**Thu 7/5/07**	**Thu 7/26/07**
87		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #1	9 days	Thu 7/5/07	Tue 7/17/07
88		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #2	9 days	Tue 7/10/07	Fri 7/20/07
89		Columns/Interior Walls to 9th Floor	10 days	Fri 7/13/07	Thu 7/26/07
90		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #3	8 days	Fri 7/13/07	Tue 7/24/07
91		**Tenth Floor**	**16 days**	**Mon 7/16/07**	**Mon 8/6/07**
92		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #1	10 days	Mon 7/16/07	Fri 7/27/07
93		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #2	9 days	Thu 7/19/07	Tue 7/31/07
94		Columns/Interior Walls to 11th Floor	10 days	Tue 7/24/07	Mon 8/6/07
95		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #3	9 days	Tue 7/24/07	Fri 8/3/07
96		**Eleventh Floor**	**16 days**	**Wed 7/25/07**	**Wed 8/15/07**
97		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #1	10 days	Wed 7/25/07	Tue 8/7/07
98		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #2	8 days	Mon 7/30/07	Wed 8/8/07
99		Columns/Interior Walls to Roof	10 days	Thu 8/2/07	Wed 8/15/07
100		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #3	9 days	Thu 8/2/07	Tue 8/14/07
101		**Roof**	**15 days**	**Mon 8/6/07**	**Fri 8/24/07**
102		Frame, Reinforce, Cast, Cure, Stress, Strip Roof Pour #1	10 days	Mon 8/6/07	Fri 8/17/07
103		Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #2	9 days	Thu 8/9/07	Tue 8/21/07
104		Columns to PH and Stair Roof	5 days	Thu 8/16/07	Wed 8/22/07



Project: 1099 New York Avenue
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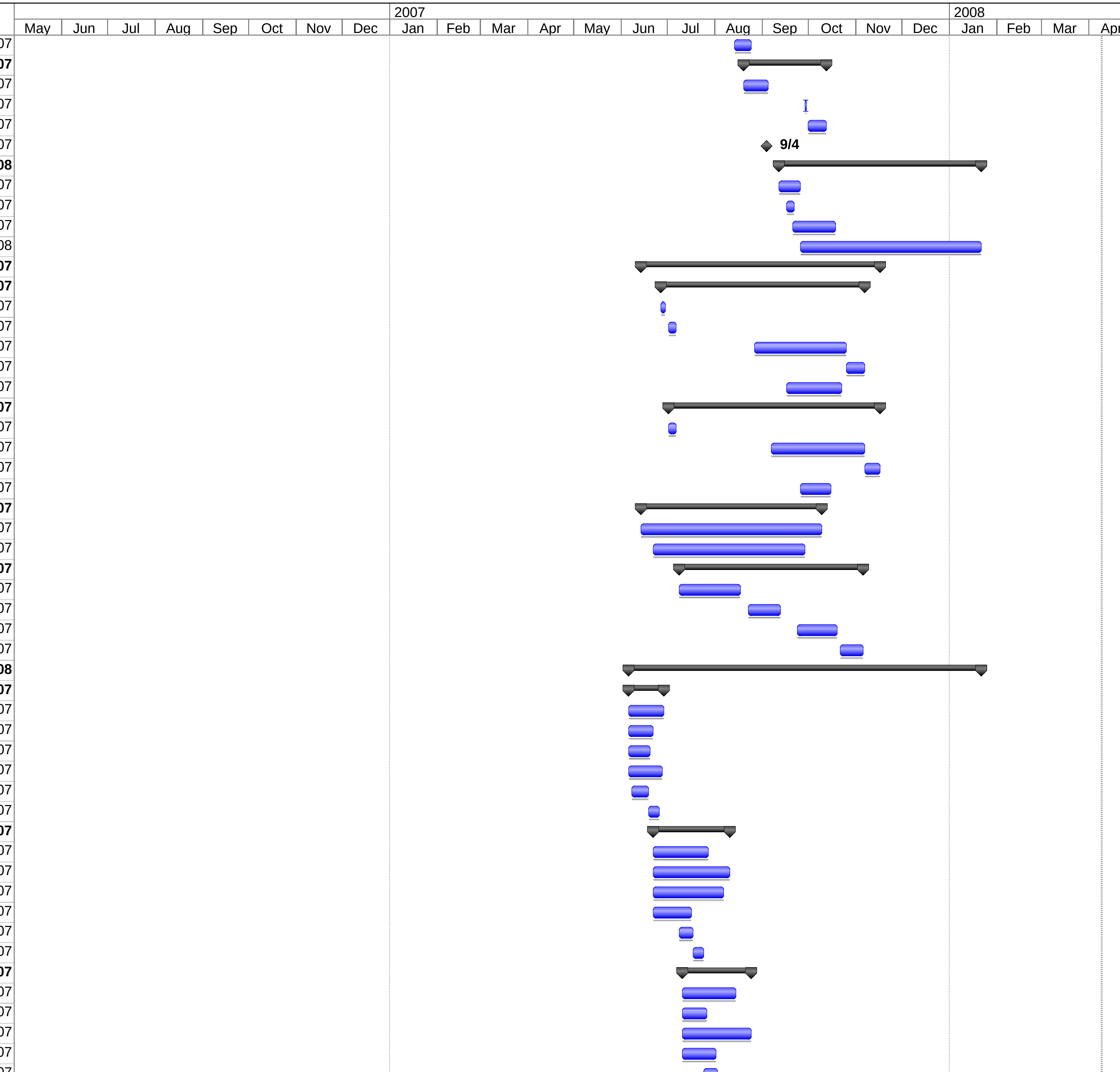
Task		Progress		Summary		External Tasks		Deadline
Split		Milestone		Project Summary		External Milestone		

ID	Task Name	Duration	Start	Finish
105	Frame, Reinforce, Cast, Cure, Stress, Strip Floor Pour #3	9 days	Tue 8/14/07	Fri 8/24/07
106	**Penthouse**	**41 days**	**Mon 8/20/07**	**Fri 10/12/07**
107	Frame, Reinforce, Cast, Cure, Strip PH and Stair Roof	12 days	Mon 8/20/07	Tue 9/4/07
108	Dismantle Crane	1 day	Sat 9/29/07	Sat 9/29/07
109	Crane Openings	10 days	Mon 10/1/07	Fri 10/12/07
110	Superstructure Complete	0 days	Tue 9/4/07	Tue 9/4/07
111	**Penthouse Construction**	**95 days**	**Wed 9/12/07**	**Mon 1/21/08**
112	Light Gauge Framing/Densglass	10 days	Wed 9/12/07	Tue 9/25/07
113	Penthouse Roof	5 days	Mon 9/17/07	Fri 9/21/07
114	EIFS at Penthouse	21 days	Fri 9/21/07	Thu 10/18/07
115	MEP in Penthouse	85 days	Wed 9/26/07	Mon 1/21/08
116	**Façade**	**113 days**	**Thu 6/14/07**	**Fri 11/16/07**
117	**West Elevation**	**96 days**	**Wed 6/27/07**	**Tue 11/6/07**
118	Mobilization	3 days	Wed 6/27/07	Fri 6/29/07
119	Layout/Set Snchors	5 days	Mon 7/2/07	Fri 7/6/07
120	Set Frames Ground Floor to Parapet	45 days	Mon 8/27/07	Thu 10/25/07
121	Caulk Curtainwall	8 days	Fri 10/26/07	Tue 11/6/07
122	Install Storefronts	27 days	Mon 9/17/07	Mon 10/22/07
123	**South Elevation**	**101 days**	**Mon 7/2/07**	**Fri 11/16/07**
124	Layout/Set Snchors	5 days	Mon 7/2/07	Fri 7/6/07
125	Set Frames Ground Floor to Parapet	44 days	Fri 9/7/07	Tue 11/6/07
126	Caulk Curtainwall	8 days	Wed 11/7/07	Fri 11/16/07
127	Install Storefronts	15 days	Wed 9/26/07	Mon 10/15/07
128	**East Elevation**	**85 days**	**Thu 6/14/07**	**Tue 10/9/07**
129	Brick Wall Assembly Gridlines 4-7	85 days	Thu 6/14/07	Tue 10/9/07
130	Brick Wall Assembly Grid Lines 1-4	71 days	Fri 6/22/07	Fri 9/28/07
131	**North Elevation**	**87 days**	**Mon 7/9/07**	**Mon 11/5/07**
132	Lay Perimeter Block	30 days	Mon 7/9/07	Fri 8/17/07
133	Light Gauge Framing/Densglass	15 days	Thu 8/23/07	Wed 9/12/07
134	Apply EIFS	21 days	Mon 9/24/07	Fri 10/19/07
135	Install Windows	11 days	Mon 10/22/07	Mon 11/5/07
136	**Interior Construction**	**165 days**	**Wed 6/6/07**	**Mon 1/21/08**
137	**B4 Level**	**17 days**	**Wed 6/6/07**	**Thu 6/28/07**
138	Set Door Frames and Hardware	17 days	Wed 6/6/07	Thu 6/28/07
139	Install Sprinklers	12 days	Wed 6/6/07	Thu 6/21/07
140	Install storm/sanitary/water piping	10 days	Wed 6/6/07	Tue 6/19/07
141	Electrical/Fire Alarm Installation	16 days	Wed 6/6/07	Wed 6/27/07
142	CMU Walls	7 days	Fri 6/8/07	Mon 6/18/07
143	Install Fans/Mechanical Equipment	5 days	Tue 6/19/07	Mon 6/25/07
144	**B3 Level**	**36 days**	**Fri 6/22/07**	**Fri 8/10/07**
145	Set Door Frames and Hardware	26 days	Fri 6/22/07	Fri 7/27/07
146	Install Sprinklers	36 days	Fri 6/22/07	Fri 8/10/07
147	Install storm/sanitary/water piping	32 days	Fri 6/22/07	Mon 8/6/07
148	Electrical/Fire Alarm Installation	17 days	Fri 6/22/07	Mon 7/16/07
149	CMU Walls	7 days	Mon 7/9/07	Tue 7/17/07
150	Install Fans/Mechanical Equipment	5 days	Wed 7/18/07	Tue 7/24/07
151	**B2 Level**	**33 days**	**Wed 7/11/07**	**Fri 8/24/07**
152	Set Door Frames and Hardware	25 days	Wed 7/11/07	Tue 8/14/07
153	Install Sprinklers	12 days	Wed 7/11/07	Thu 7/26/07
154	Install storm/sanitary/water piping	33 days	Wed 7/11/07	Fri 8/24/07
155	Electrical/Fire Alarm Installation	16 days	Wed 7/11/07	Wed 8/1/07
156	CMU Walls	7 days	Wed 7/25/07	Thu 8/2/07



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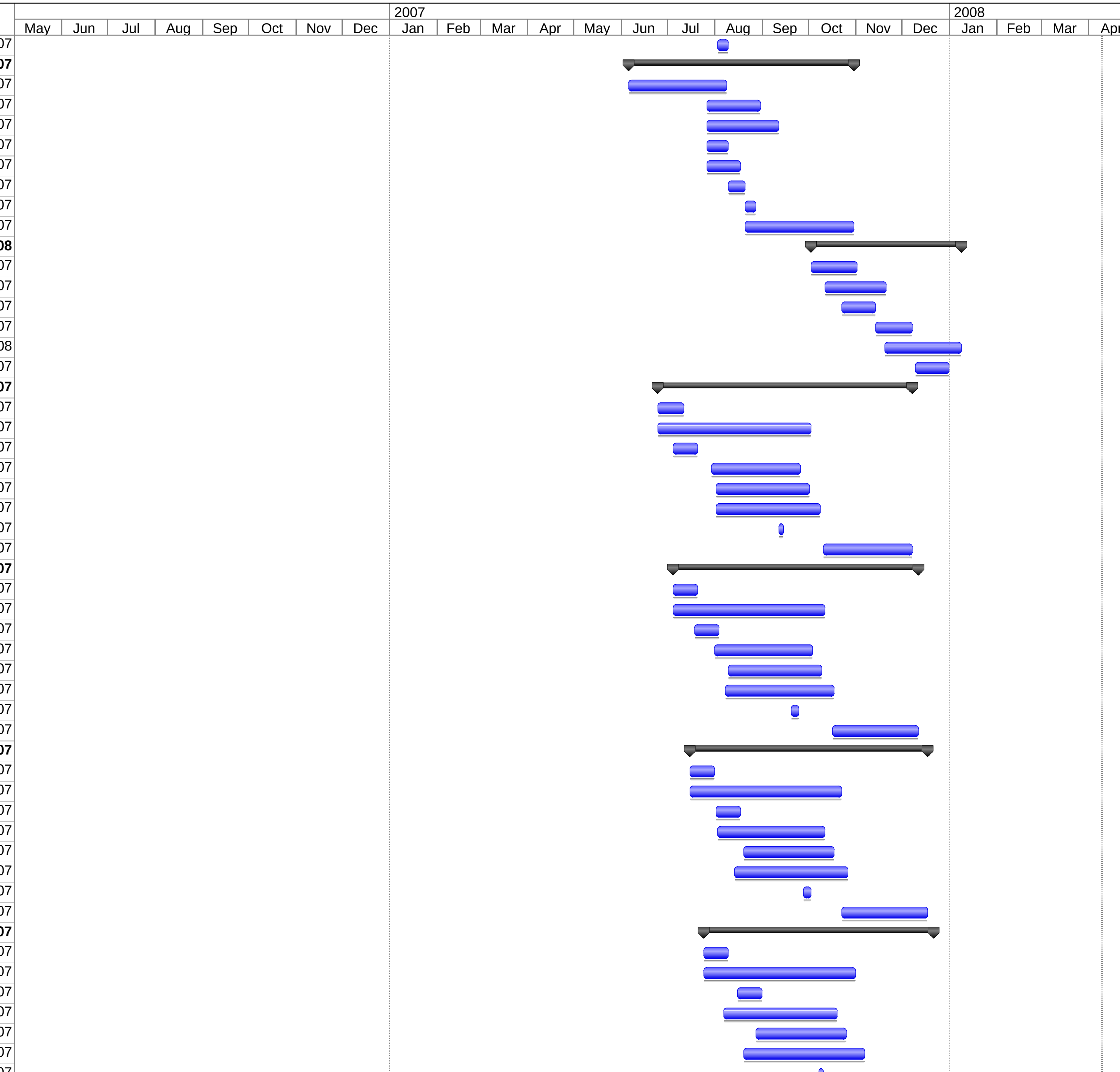
Task		Progress		Summary		External Tasks		Deadline	
Split		Milestone		Project Summary		External Milestone			

ID	Task Name	Duration	Start	Finish
157	Install Fans/Mechanical Equipment	5 days	Fri 8/3/07	Thu 8/9/07
158	**B1 Level**	**106 days**	**Wed 6/6/07**	**Tue 10/30/07**
159	Set/Connect Switchgear	46 days	Wed 6/6/07	Wed 8/8/07
160	Set Door Frames and Hardware	25 days	Fri 7/27/07	Thu 8/30/07
161	Install Sprinklers/Fire Pumps	33 days	Fri 7/27/07	Tue 9/11/07
162	Install storm/sanitary/water piping	10 days	Fri 7/27/07	Thu 8/9/07
163	Electrical/Fire Alarm Installation	16 days	Fri 7/27/07	Fri 8/17/07
164	CMU Walls	7 days	Fri 8/10/07	Mon 8/20/07
165	Install Fans/Mechanical Equipment	5 days	Tue 8/21/07	Mon 8/27/07
166	Construct Health Club	52 days	Tue 8/21/07	Tue 10/30/07
167	**Main Lobby**	**70 days**	**Wed 10/3/07**	**Tue 1/8/08**
168	Mechanical/Electrical Installation	22 days	Wed 10/3/07	Thu 11/1/07
169	Install Sprinkler	28 days	Fri 10/12/07	Tue 11/20/07
170	Frame, Hang, Finish Perimeter Walls	16 days	Tue 10/23/07	Tue 11/13/07
171	Frame, Hang, Finish Drywall Ceiling	18 days	Wed 11/14/07	Fri 12/7/07
172	Install Light Fixtures	36 days	Tue 11/20/07	Tue 1/8/08
173	Install Stone Floors and Walls	16 days	Mon 12/10/07	Mon 12/31/07
174	**Second Floor**	**121 days**	**Mon 6/25/07**	**Fri 12/7/07**
175	Hang Risers/Install Core Mechanical System	13 days	Mon 6/25/07	Wed 7/11/07
176	Install Core Plumbing Pipe/Fixtures	73 days	Mon 6/25/07	Tue 10/2/07
177	Install/Hydro Core Sprinkler	12 days	Thu 7/5/07	Fri 7/20/07
178	Frame/Hang Core Walls and Ceilings	42 days	Mon 7/30/07	Tue 9/25/07
179	Install Electrical/Fire Alarm System	44 days	Thu 8/2/07	Mon 10/1/07
180	Install Toilet Partitions and Counters	49 days	Thu 8/2/07	Mon 10/8/07
181	Install Doors and Hardware	3 days	Wed 9/12/07	Fri 9/14/07
182	Frame, Hang, Finish Perimeter Drywall	42 days	Thu 10/11/07	Fri 12/7/07
183	**Third Floor**	**115 days**	**Thu 7/5/07**	**Tue 12/11/07**
184	Hang Risers/Install Core Mechanical System	12 days	Thu 7/5/07	Fri 7/20/07
185	Install Core Plumbing Pipe/Fixtures	72 days	Thu 7/5/07	Thu 10/11/07
186	Install/Hydro Core Sprinkler	12 days	Thu 7/19/07	Fri 8/3/07
187	Frame/Hang Core Walls and Ceilings	47 days	Wed 8/1/07	Wed 10/3/07
188	Install Electrical/Fire Alarm System	44 days	Fri 8/10/07	Tue 10/9/07
189	Install Toilet Partitions and Counters	52 days	Wed 8/8/07	Wed 10/17/07
190	Install Doors and Hardware	3 days	Thu 9/20/07	Mon 9/24/07
191	Frame, Hang, Finish Perimeter Drywall	40 days	Wed 10/17/07	Tue 12/11/07
192	**Fourth Floor**	**112 days**	**Mon 7/16/07**	**Mon 12/17/07**
193	Hang Risers/Install Core Mechanical System	12 days	Mon 7/16/07	Tue 7/31/07
194	Install Core Plumbing Pipe/Fixtures	72 days	Mon 7/16/07	Mon 10/22/07
195	Install/Hydro Core Sprinkler	12 days	Thu 8/2/07	Fri 8/17/07
196	Frame/Hang Core Walls and Ceilings	51 days	Fri 8/3/07	Thu 10/11/07
197	Install Electrical/Fire Alarm System	44 days	Mon 8/20/07	Wed 10/17/07
198	Install Toilet Partitions and Counters	55 days	Tue 8/14/07	Fri 10/26/07
199	Install Doors and Hardware	4 days	Fri 9/28/07	Tue 10/2/07
200	Frame, Hang, Finish Perimeter Drywall	40 days	Tue 10/23/07	Mon 12/17/07
201	**Fifth Floor**	**109 days**	**Wed 7/25/07**	**Fri 12/21/07**
202	Hang Risers/Install Core Mechanical System	12 days	Wed 7/25/07	Thu 8/9/07
203	Install Core Plumbing Pipe/Fixtures	72 days	Wed 7/25/07	Wed 10/31/07
204	Install/Hydro Core Sprinkler	12 days	Thu 8/16/07	Fri 8/31/07
205	Frame/Hang Core Walls and Ceilings	55 days	Tue 8/7/07	Fri 10/19/07
206	Install Electrical/Fire Alarm System	44 days	Tue 8/28/07	Thu 10/25/07
207	Install Toilet Partitions and Counters	58 days	Mon 8/20/07	Tue 11/6/07
208	Install Doors and Hardware	3 days	Mon 10/8/07	Wed 10/10/07



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Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

ID	Task Name	Duration	Start	Finish
209	Frame, Hang, Finish Perimeter Drywall	40 days	Mon 10/29/07	Fri 12/21/07
210	**Sixth Floor**	**107 days**	**Fri 8/3/07**	**Fri 12/28/07**
211	Hang Risers/Install Core Mechanical System	12 days	Fri 8/3/07	Mon 8/20/07
212	Install Core Plumbing Pipe/Fixtures	72 days	Fri 8/3/07	Fri 11/9/07
213	Install/Hydro Core Sprinkler	13 days	Thu 8/30/07	Mon 9/17/07
214	Frame/Hang Core Walls and Ceilings	56 days	Tue 8/14/07	Mon 10/29/07
215	Install Electrical/Fire Alarm System	43 days	Thu 9/6/07	Fri 11/2/07
216	Install Toilet Partitions and Counters	61 days	Fri 8/24/07	Thu 11/15/07
217	Install Doors and Hardware	3 days	Tue 10/16/07	Thu 10/18/07
218	Frame, Hang, Finish Perimeter Drywall	41 days	Fri 11/2/07	Fri 12/28/07
219	**Seventh Floor**	**107 days**	**Tue 8/14/07**	**Tue 1/8/08**
220	Hang Risers/Install Core Mechanical System	12 days	Tue 8/14/07	Wed 8/29/07
221	Install Core Plumbing Pipe/Fixtures	72 days	Tue 8/14/07	Tue 11/20/07
222	Install/Hydro Core Sprinkler	13 days	Fri 9/14/07	Mon 10/1/07
223	Frame/Hang Core Walls and Ceilings	55 days	Thu 8/23/07	Tue 11/6/07
224	Install Electrical/Fire Alarm System	43 days	Fri 9/14/07	Mon 11/12/07
225	Install Toilet Partitions and Counters	66 days	Thu 8/30/07	Wed 11/28/07
226	Install Doors and Hardware	3 days	Wed 10/24/07	Fri 10/26/07
227	Frame, Hang, Finish Perimeter Drywall	8 days	Fri 12/28/07	Tue 1/8/08
228	**Eighth Floor**	**109 days**	**Thu 8/23/07**	**Mon 1/21/08**
229	Hang Risers/Install Core Mechanical System	13 days	Thu 8/23/07	Mon 9/10/07
230	Install Core Plumbing Pipe/Fixtures	105 days	Thu 8/23/07	Tue 1/15/08
231	Install/Hydro Core Sprinkler	14 days	Wed 11/14/07	Mon 12/3/07
232	Frame/Hang Core Walls and Ceilings	92 days	Tue 9/4/07	Tue 1/8/08
233	Install Electrical/Fire Alarm System	82 days	Mon 9/24/07	Mon 1/14/08
234	Install Toilet Partitions and Counters	98 days	Fri 9/7/07	Mon 1/21/08
235	Install Doors and Hardware	4 days	Mon 12/24/07	Thu 12/27/07
236	Frame, Hang, Finish Perimeter Drywall	8 days	Mon 12/31/07	Wed 1/9/08
237	**Ninth Floor**	**91 days**	**Tue 9/4/07**	**Mon 1/7/08**
238	Hang Risers/Install Core Mechanical System	12 days	Tue 9/4/07	Wed 9/19/07
239	Install Core Plumbing Pipe/Fixtures	86 days	Tue 9/4/07	Mon 12/31/07
240	Install/Hydro Core Sprinkler	12 days	Wed 10/31/07	Thu 11/15/07
241	Frame/Hang Core Walls and Ceilings	73 days	Thu 9/13/07	Fri 12/21/07
242	Install Electrical/Fire Alarm System	64 days	Tue 10/2/07	Fri 12/28/07
243	Install Toilet Partitions and Counters	81 days	Tue 9/18/07	Mon 1/7/08
244	Install Doors and Hardware	3 days	Mon 12/10/07	Wed 12/12/07
245	Frame, Hang, Finish Perimeter Drywall	8 days	Wed 12/19/07	Fri 12/28/07
246	**Tenth Floor**	**74 days**	**Thu 9/13/07**	**Mon 12/24/07**
247	Hang Risers/Install Core Mechanical System	10 days	Thu 9/13/07	Wed 9/26/07
248	Install Core Plumbing Pipe/Fixtures	70 days	Thu 9/13/07	Tue 12/18/07
249	Install/Hydro Core Sprinkler	12 days	Wed 10/17/07	Thu 11/1/07
250	Frame/Hang Core Walls and Ceilings	56 days	Mon 9/24/07	Fri 12/7/07
251	Install Electrical/Fire Alarm System	47 days	Wed 10/10/07	Thu 12/13/07
252	Install Toilet Partitions and Counters	64 days	Thu 9/27/07	Mon 12/24/07
253	Install Doors and Hardware	3 days	Mon 11/26/07	Wed 11/28/07
254	Frame, Hang, Finish Perimeter Drywall	7 days	Mon 12/10/07	Tue 12/18/07
255	**Eleventh Floor**	**60 days**	**Mon 9/24/07**	**Thu 12/13/07**
256	Hang Risers/Install Core Mechanical System	13 days	Mon 9/24/07	Tue 10/9/07
257	Install Core Plumbing Pipe/Fixtures	56 days	Mon 9/24/07	Fri 12/7/07
258	Install/Hydro Core Sprinkler	12 days	Wed 10/3/07	Thu 10/18/07
259	Frame/Hang Core Walls and Ceilings	43 days	Wed 10/3/07	Fri 11/30/07
260	Install Electrical/Fire Alarm System	44 days	Mon 10/8/07	Thu 12/6/07

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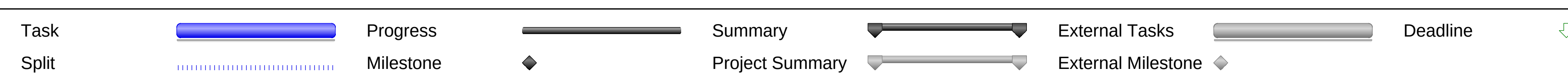
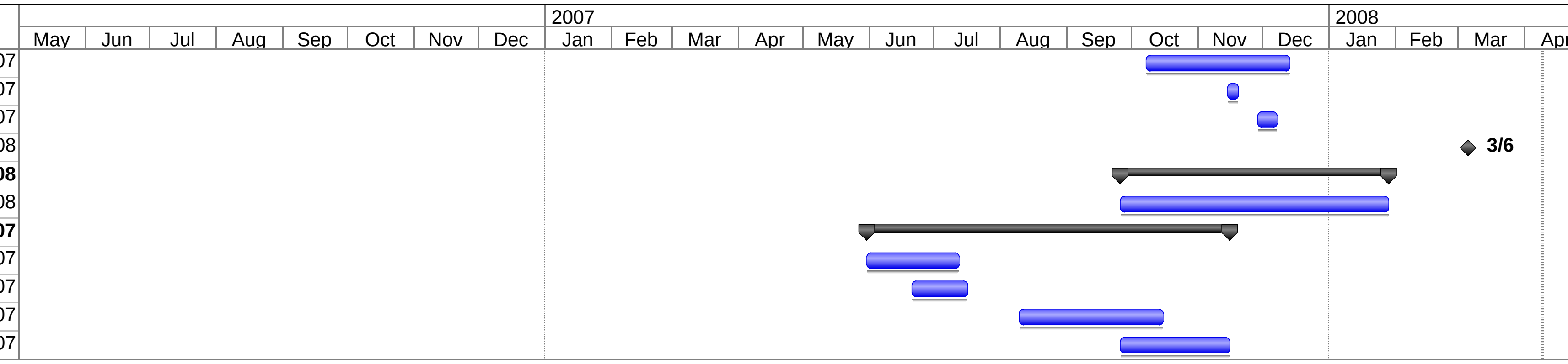


ID	Task Name	Duration	Start	Finish
261	Install Toilet Partitions and Counters	49 days	Mon 10/8/07	Thu 12/13/07
262	Install Doors and Hardware	3 days	Thu 11/15/07	Mon 11/19/07
263	Frame, Hang, Finish Perimeter Drywall	7 days	Thu 11/29/07	Fri 12/7/07
264	Substantial Completion	0 days	Thu 3/6/08	Thu 3/6/08
265	**Elevator Construction**	**90 days**	**Wed 9/26/07**	**Mon 1/28/08**
266	Elevator Installation	90 days	Wed 9/26/07	Mon 1/28/08
267	**Sitework**	**122 days**	**Thu 5/31/07**	**Thu 11/15/07**
268	Install Utilities	31 days	Thu 5/31/07	Thu 7/12/07
269	Place Curb/Gutter	18 days	Thu 6/21/07	Mon 7/16/07
270	Install Electrical Service	48 days	Fri 8/10/07	Mon 10/15/07
271	Lay Concrete Base and Pavers	38 days	Wed 9/26/07	Thu 11/15/07



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Task		Progress		Summary		External Tasks		Deadline	
Split		Milestone		Project Summary		External Milestone			

Appendix C

Daylighting & Views Calculations

Window Type	Glazing Dimensions	Glazing Area	Quantity	Total Area	Geometry	Min. Visible Transmittance	Visible Transmittance	Height Factor	Occupied Floor Area	Daylight Factor (Each)	Daylight Factor (Floor)
Ground Floor											
Façade Type 1 (Daylight)	5'-3 1/2" x 4'-4 1/2"	23.14	55	1,272.70	0.1	0.7	0.85	1.4	8,344	2.59%	5.56%
Façade Type 1 (Vision)	5'-3 1/2" x 5'-0"	26.45	55	1,454.75	0.1	0.4	0.85	0.8	8,344	2.96%	
Level 2											
Façade Type 1 (Daylight)	5'-3 1/2" x 4'-4 1/2"	23.14	59	1,365.26	0.1	0.7	0.85	1.4	10,397	2.23%	4.78%
Façade Type 1 (Vision)	5'-3 1/2" x 5'-0"	26.45	59	1,560.55	0.1	0.4	0.85	0.8	10,397	2.55%	
Façade Type 2	4'-11 1/2" x 5'-1 1/2"	25.42	19	482.98	0.1	0.4		0.8	2,288		
Level 3											
Façade Type 1 (Daylight)	5'-3 1/2" x 4'-4 1/2"	23.14	59	1,365.26	0.1	0.7	0.85	1.4	10,045	2.31%	4.95%
Façade Type 1 (Vision)	5'-3 1/2" x 5'-0"	26.45	59	1,560.55	0.1	0.4	0.85	0.8	10,045	2.64%	
Façade Type 2	4'-11 1/2" x 5'-1 1/2"	25.42	19	482.98	0.1	0.4		0.8	2,992		
Level 4											
Façade Type 1 (Daylight)	5'-3 1/2" x 4'-4 1/2"	23.14	59	1,365.26	0.1	0.7	0.85	1.4	10,045	2.31%	4.95%
Façade Type 1 (Vision)	5'-3 1/2" x 5'-0"	26.45	59	1,560.55	0.1	0.4	0.85	0.8	10,045	2.64%	
Façade Type 2	4'-11 1/2" x 5'-1 1/2"	25.42	19	482.98	0.1	0.4		0.8	2,992		
Level 5											
Façade Type 1 (Daylight)	5'-3 1/2" x 4'-4 1/2"	23.14	59	1,365.26	0.1	0.7	0.85	1.4	10,045	2.31%	4.95%
Façade Type 1 (Vision)	5'-3 1/2" x 5'-0"	26.45	59	1,560.55	0.1	0.4	0.85	0.8	10,045	2.64%	
Façade Type 2	4'-11 1/2" x 5'-1 1/2"	25.42	19	482.98	0.1	0.4		0.8	2,992		
Level 6											
Façade Type 1 (Daylight)	5'-3 1/2" x 4'-4 1/2"	23.14	59	1,365.26	0.1	0.7	0.85	1.4	10,045	2.31%	4.95%
Façade Type 1 (Vision)	5'-3 1/2" x 5'-0"	26.45	59	1,560.55	0.1	0.4	0.85	0.8	10,045	2.64%	
Façade Type 2	4'-11 1/2" x 5'-1 1/2"	25.42	19	482.98	0.1	0.4		0.8	2,992		
Level 7											
Façade Type 1 (Daylight)	5'-3 1/2" x 4'-4 1/2"	23.14	59	1,365.26	0.1	0.7	0.85	1.4	7,905	2.94%	6.29%
Façade Type 1 (Vision)	5'-3 1/2" x 5'-0"	26.45	59	1,560.55	0.1	0.4	0.85	0.8	7,905	3.36%	
Façade Type 2	4'-11 1/2" x 5'-1 1/2"	25.42	31	788.02	0.1	0.4		0.8	4,124		
Level 8											
Façade Type 1 (Daylight)	5'-3 1/2" x 4'-4 1/2"	23.14	59	1,365.26	0.1	0.7	0.85	1.4	7,905	2.94%	6.29%
Façade Type 1 (Vision)	5'-3 1/2" x 5'-0"	26.45	59	1,560.55	0.1	0.4	0.85	0.8	7,905	3.36%	
Façade Type 2	4'-11 1/2" x 5'-1 1/2"	25.42	31	788.02	0.1	0.4		0.8	4,124		
Level 9											
Façade Type 1 (Daylight)	5'-3 1/2" x 4'-4 1/2"	23.14	59	1,365.26	0.1	0.7	0.85	1.4	7,905	2.94%	6.29%
Façade Type 1 (Vision)	5'-3 1/2" x 5'-0"	26.45	59	1,560.55	0.1	0.4	0.85	0.8	7,905	3.36%	
Façade Type 2	4'-11 1/2" x 5'-1 1/2"	25.42	31	788.02	0.1	0.4		0.8	4,124		
Level 10											
Façade Type 1 (Daylight)	5'-3 1/2" x 4'-4 1/2"	23.14	59	1,365.26	0.1	0.7	0.85	1.4	7,905	2.94%	6.29%
Façade Type 1 (Vision)	5'-3 1/2" x 5'-0"	26.45	59	1,560.55	0.1	0.4	0.85	0.8	7,905	3.36%	
Façade Type 2	4'-11 1/2" x 5'-1 1/2"	25.42	31	788.02	0.1	0.4		0.8	4,124		
Level 11											
Façade Type 1 (Daylight)	5'-3 1/2" x 4'-4 1/2"	23.14	59	1,365.26	0.1	0.7	0.85	1.4	7,905	2.94%	6.29%
Façade Type 1 (Vision)	5'-3 1/2" x 5'-0"	26.45	59	1,560.55	0.1	0.4	0.85	0.8	7,905	3.36%	
Façade Type 2	4'-11 1/2" x 5'-1 1/2"	25.42	31	788.02	0.1	0.4		0.8	4,124		

Appendix D

Structural Hand Calculations for Slab Redesign

JAMES G. DAVIS CONSTRUCTION CORPORATION

DAVIS

1430 Spring Hill Road, Suite 450
McLean, VA 22102
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Fax (703) 442-8010

NOTES

TO
FROM
DATE TIME
PROJECT
PROJECT NUMBER

MEMO ☐ CONFERENCE ☐ TELECON ☐

ATTENDEES:

14' x 18' PANEL → $l_2/l_1 = 1.29$
$f'_c = 4{,}000$ psi $f_y = 60{,}000$ psi
8" DROP PANELS
LIVE LOAD = 30 psf SNOW: 30 psf GREEN ROOF: 26 psf SELF: 100 psf

h = 8" > 4" NO BEAMS ∴ $\alpha = 0$ & $\beta_t = 0$
$w_u = 1.2D + 1.6L_r + 0.5S$
$w_u = 1.2(26+100) + 1.6(30) + 0.5(30) = 214$ psf

SHORT SPAN

$$M_o = \frac{w l_2 l_n^2}{8} = \frac{(0.214)(18)(12.83)^2}{8} = 79.3 \text{ ft-k}$$

FROM ACI 13.6.3:
INT. NEG. $M_u = 0.70 M_o = 55.5$ ft-k
EXT. NEG $M_u = 0.26 M_o = 20.6$ ft-k
POS $M_u = 0.52 M_o = 41.2$ ft-k

COL. STRIP WIDTH = $2 \times 14/4 = 7$ ft
FROM A.4 IN APPENDIX 4, COL STRIP SUPPORTS:
75% INT. NEG $M_u = 41.6$ ft-k
75% EXT. NEG $M_u = 15.5$ ft-k
60% POS. $M_u = 24.7$ ft-k

SHORT SPAN	COL. STRIP	MIDDLE STRIP
INT. NEG.	41.6	13.9
EXT. NEG.	15.5	5.1
POS.	24.7	16.5

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ATTENDEES:

LONG SPAN

$$M_o = \frac{(0.214)(14)(16)^2}{8} = 95.9 \text{ ft-K}$$

FROM ACI 13.6.3

INT. NEG. M_u = 67.1 ft-K
EXT. NEG. M_u = 24.9 ft-K
POS M_u = 49.9 ft-K

FROM APPENDIX A.4

LONG SPAN	COL. STRIP	MIDDLE STRIP
INT. NEG	50.3	16.8
EXT. NEG	18.7	6.2
POS.	29.9	20

$$d^2 = \frac{M_u}{\phi \rho f_y b(1-0.59\rho f_y/f'_c)} = \frac{M_u}{(0.9)(0.0206)(60{,}000)(12)(1-(0.59)(0.0206)(60/4)}$$

$$d = \sqrt{\frac{M_u}{10{,}915}}$$

18 ft SPAN: $d = \sqrt{\frac{116 \times 12}{33} \times \frac{12{,}000}{10{,}915}} = 2.53''$ → USE 7"

14 ft SPAN: $d = \sqrt{\frac{12.83 \times 12}{36} \times \frac{12{,}000}{10{,}915}} = 2.2''$ → USE 6"

FOR SHRINKAGE & TEMP.

$0.0018 \times 8'' \times 12'' = 0.173 \text{ in}^2$

18 ft SPAN: $\rho_{min} = \frac{0.173}{7 \times 12} = 0.0021$

14 ft SPAN: $\rho_{min} = \frac{0.173}{6 \times 12} = 0.0024$

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ATTENDEES:

	LOCATION	M_u (ft-k)	b (in)	d (in)	$M_u \times 12/b$ (ft-k)	ρ	A_s (in²)	BARS
LONG SPAN								
1. (2) HALF COL.	INT. NEG.	50.3	84	7	7.2	0.0025	0.236	#5 @ 12"
2.	EXT. NEG.	18.7	84	7	2.67	0.0021	0.2	#5 @ 12"
3.	POS.	29.9	84	7	4.3	0.0021	0.2	#5 @ 12"
4. MIDDLE	INT. NEG.	16.8	132	7	1.5	0.0021	0.2	#5 @ 12"
5.	EXT. NEG	6.2	132	7	0.6	0.0021	0.2	#5 @ 12"
6.	POS.	20	132	7	1.8	0.0021	0.2	#5 @ 12"
SHORT SPAN								
7. EXT. COL	NEG.	15.5	42	6	4.4	0.0024	0.23	#5 @ 12"
8.	POS.	24.7	42	6	7.1	0.0029	0.28	#5 @ 12"
9. MIDDLE	NEG.	13.9	84	6	2.0	0.0024	0.23	#5 @ 12"
10.	POS.	16.5	84	6	2.4	0.0024	0.23	#5 @ 12"
11. INT. COL.	NEG.	41.6	42	6	11.9	0.005	0.48	#5 @ 7½"
12.	POS.	24.7	42	6	7.1	0.0029	0.28	#5 @ 12"

$$M_u(12\ \text{in/ft}) = 0.9 A_s (60\ \text{ksi})\left(d - \frac{1.96 A_s}{2}\right)$$

1. $A_s = 0.236 \rightarrow 0.236/(8\times12) = 0.0025 > 0.0021$ OK
2. $A_s = 0.09 \rightarrow 0.09/(8\times12) = 0.0009 < 0.0021$ NG.
3. $A_s = 0.14 \rightarrow 0.14/(8\times12) = 0.0015 < 0.0021$ NG.
4. $A_s = 0.05 \rightarrow 0.05/(8\times12) = 0.0005 < 0.0021$ N.G.
5. $A_s = 0.019 \rightarrow 0.019/(8\times12) = 0.0002 < 0.0021$ N.G.
6. $A_s = 0.058 \rightarrow 0.058/(8\times12) = 0.0006 < 0.0021$ N.G.
7. $A_s = 0.17 \rightarrow 0.17/(8\times12) = 0.0018 < 0.0024$ N.G.
8. $A_s = 0.28 \rightarrow 0.28/(8\times12) = 0.0029 > 0.0024$ OK
9. $A_s = 0.075 \rightarrow 0.075/(8\times12) = 0.0008 < 0.0024$ N.G.
10. $A_s = 0.09 \rightarrow 0.09/(8\times12) = 0.0009 < 0.0024$ N.G.
11. $A_s = 0.48 \rightarrow 0.48/(8\times12) = 0.0050 > 0.0024$ OK
12. $A_s = 0.28 \rightarrow 0.28/(8\times12) = 0.0029 > 0.0024$ OK

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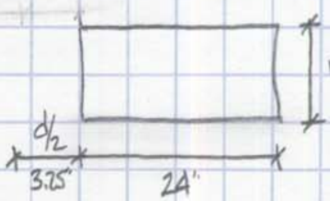
ATTENDEES:

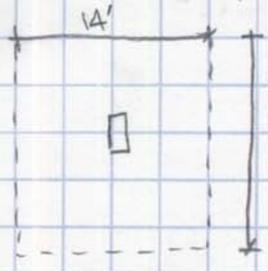
NOMINAL SHEAR STRENGTH

$V_c = 4\sqrt{f'_c}\, b_o d \rightarrow \phi V_c = (0.75)(4)(\sqrt{4,000})(90.3)(6.5") = 111,366$ lbs.



BASED ON TRIBUTARY AREA

$V_u = (214.2 \text{ psf})(18' \times 14') = 53,978 \text{ lbs.} < \phi V_c = 111,366 \text{ lbs}$ OK



∴ NO ADDT'L SHEAR REINFORCEMENT REQUIRED

COL. DESIGN

$P_n = 0.85 f'_c A_c + A_{st} f_y$

$\phi P_n = 0.65\left[(0.85)(4,000)(336) + (4.00)(60,000)\right] = 898,560$ lb

$a = \dfrac{A_s f_y}{0.85 f'_c b} = 5.04$

$\phi P_n = 898,560 > P_u = 53,978$ lbs. OK

$\rightarrow M_n = 0.85 f'_c a b\left(\frac{h}{2} - \frac{a}{2}\right) + A'_s f'_s\left(\frac{h}{2} - d'\right) + A_s f_s\left(d - \frac{h}{2}\right)$

$\phi M_n = 0.65\left[(0.85)(4)(5.04)(14)\left(\frac{24}{2} - \frac{5.04}{2}\right) + (2)(60)\left(\frac{24}{2} - 2.5\right) + (2)(60)\left(21.5 - \frac{24}{2}\right)\right]$

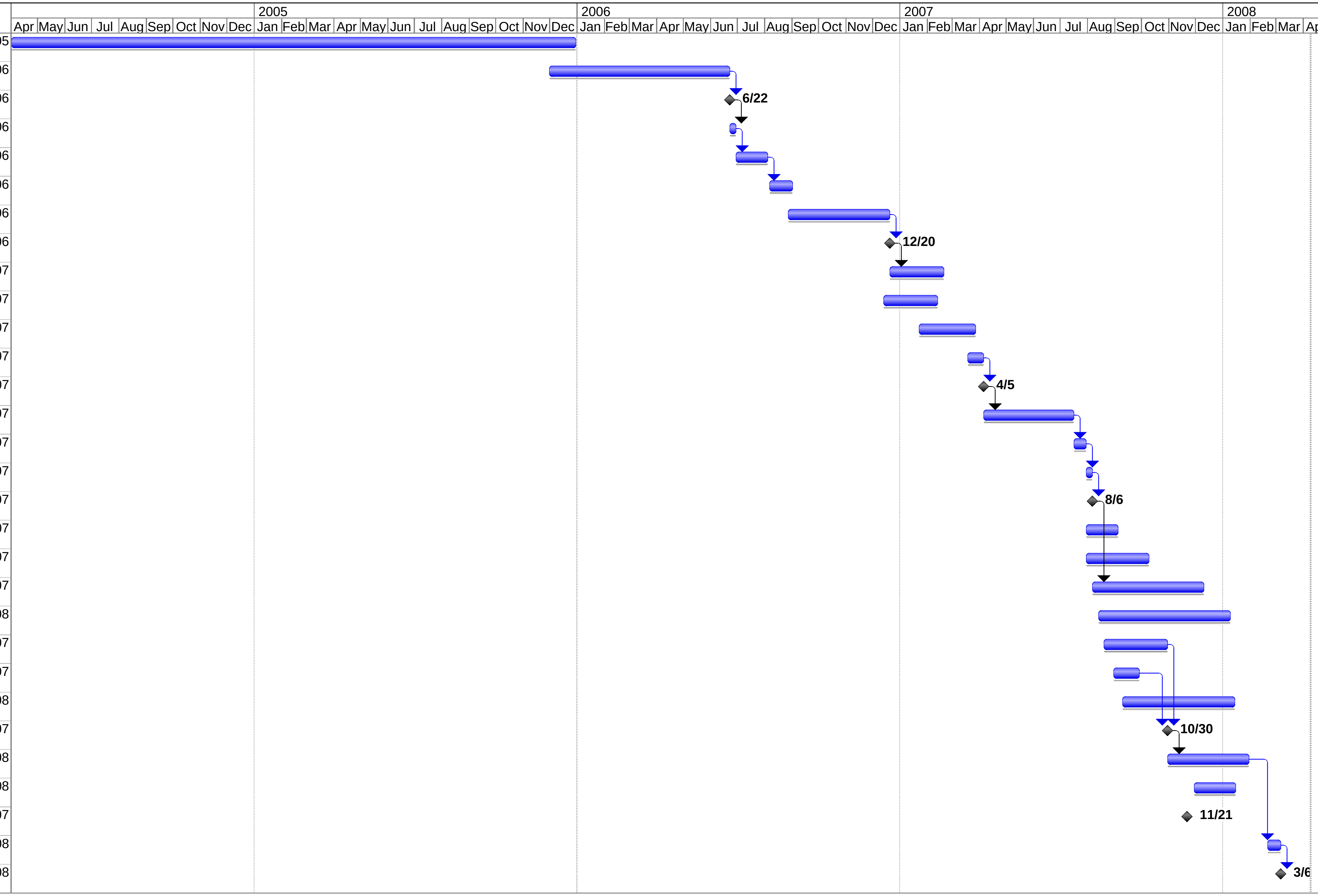
$\phi M_n = 247 \text{ ft-k} > M_u = 95.9 \text{ ft-k}$ OK

Appendix E

3D Coordination Schedule Comparison

Thesis Final Report
Appendix E
Project Schedule Summary

ID		Task Name	Duration	Start	Finish
1		Design Phase	456 days	Fri 4/2/04	ri 12/30/05
2		Procurement of Construction Services	146 days	hu 12/1/05	hu 6/22/06
3		Notice to Proceed	0 days	hu 6/22/06	hu 6/22/06
4		Mobilize Site	5 days	Fri 6/23/06	hu 6/29/06
5		Demolish Existing Conditions	26 days	Fri 6/30/06	Fri 8/4/06
6		Drive Soldier Beams	20 days	Mon 8/7/06	Fri 9/1/06
7		Excavtion & Tiebacks	83 days	on 8/28/06	d 12/20/06
8		Excavation Complete	0 days	d 12/20/06	d 12/20/06
9		Install Foundation Drains and Sumps	43 days?	u 12/21/06	on 2/19/07
10		Place Footings, Grade Beams Elevator Pits	43 days	u 12/14/06	on 2/12/07
11		Form, Reinforce, Pour Level B4-B1	46 days	ue 1/23/07	ue 3/27/07
12		Form, Reinforce, Pour Ground Level Slab	14 days	on 3/19/07	Thu 4/5/07
13		Substructure Complete to Grade	0 days	Thu 4/5/07	Thu 4/5/07
14		Form, Reinforce, Pour Levels 2-11	72 days	Fri 4/6/07	on 7/16/07
15		Form, Reinforce, Pour Roof	10 days	ue 7/17/07	on 7/30/07
16		Penthouse Structure	5 days	ue 7/31/07	Mon 8/6/07
17		Superstructure Complete	0 days	Mon 8/6/07	Mon 8/6/07
18		Light Gauge Framing at North & East Elev.	26 days	ue 7/31/07	Tue 9/4/07
19		Curtainwall at 11th St. Elev.	51 days	ue 7/31/07	ue 10/9/07
20		Garage Interiors	90 days	Tue 8/7/07	n 12/10/07
21		MEP in Penthouse	107 days	ue 8/14/07	Wed 1/9/08
22		Curtainwall at NY Avenue	52 days	on 8/20/07	e 10/30/07
23		Penthouse Roof and Main Roof	21 days	Fri 8/31/07	Fri 9/28/07
24		Elevator Installation	91 days	on 9/10/07	on 1/14/08
25		Façade and Roof Complete	0 days	e 10/30/07	e 10/30/07
26		Main Lobby Construction	66 days	d 10/31/07	ed 1/30/08
27		Typical Core Construction Floors 1-11	33 days	ri 11/30/07	ue 1/15/08
28		Tenant Full Access	0 days	d 11/21/07	d 11/21/07
29		Inspections	11 days	hu 2/21/08	Thu 3/6/08
30		Substantial Completion	0 days	Thu 3/6/08	Thu 3/6/08

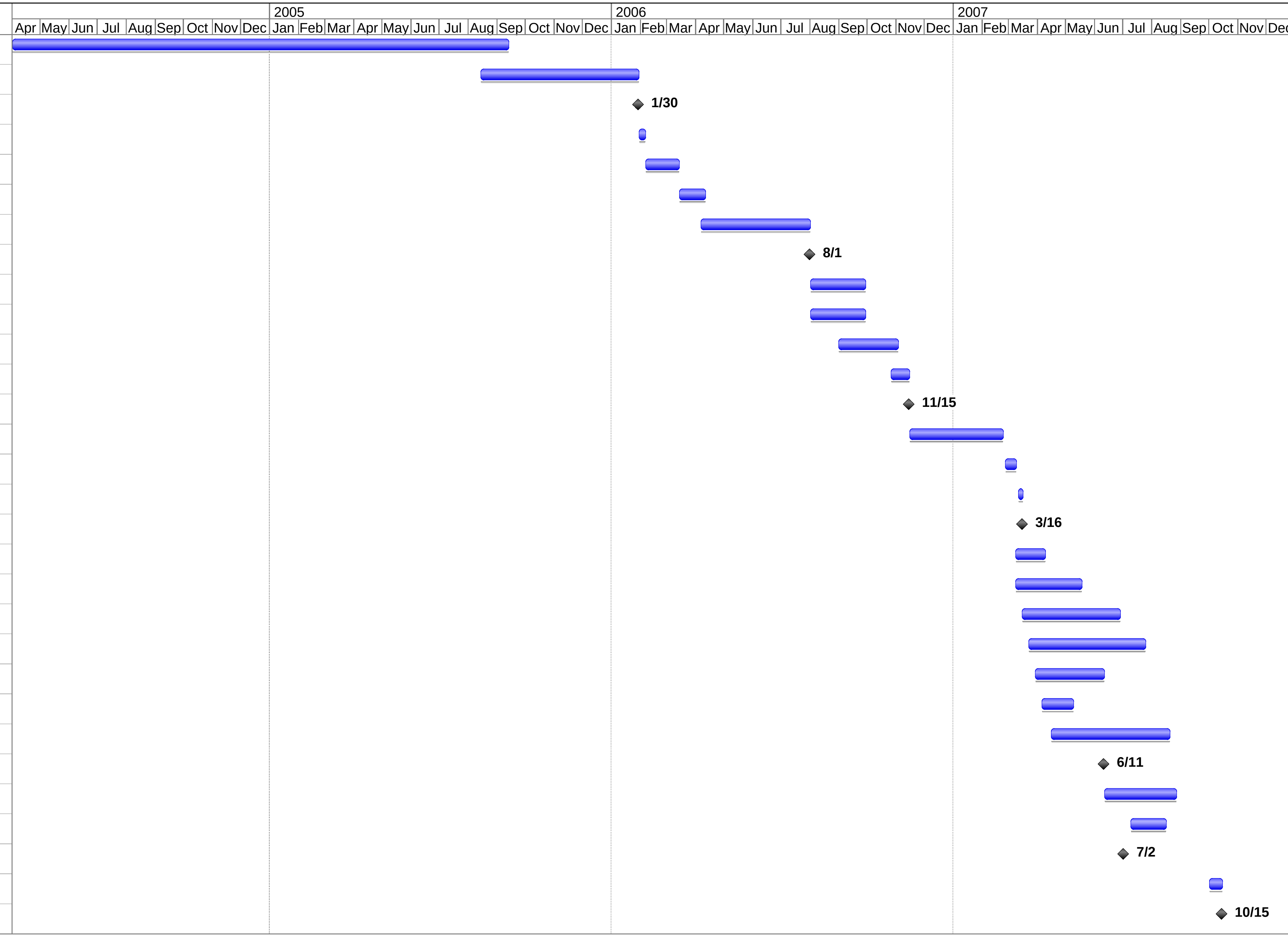


Project: 1099 New York Avenue
Date: Wed 4/9/08

Task		Progress		Summary		External Tasks		Deadline	
Split		Milestone		Project Summary		External Milestone			

Thesis Final Report
Appendix E
Decreased Project Schedule Summary

ID		Task Name	Duration	Start	Finish	Predecessors
1		Design Phase	378 days	Fri 4/2/04	Tue 9/13/05	
2		Procurement of Construction Se	121 days	Mon 8/15/05	Mon 1/30/06	
3		Notice to Proceed	0 days	Mon 1/30/06	Mon 1/30/06	
4		Mobilize Site	5 days	Tue 1/31/06	Mon 2/6/06	
5		Demolish Existing Conditions	26 days	Tue 2/7/06	Tue 3/14/06	
6		Drive Soldier Beams	20 days	Wed 3/15/06	Tue 4/11/06	
7		Excavtion & Tiebacks	83 days	Fri 4/7/06	Tue 8/1/06	
8		Excavation Complete	0 days	Tue 8/1/06	Tue 8/1/06	
9		Install Foundation Drains and S	43 days	Wed 8/2/06	Fri 9/29/06	
10		Place Footings, Grade Beams E	43 days	Wed 8/2/06	Fri 9/29/06	
11		Form, Reinforce, Pour Level B4	46 days	Fri 9/1/06	Fri 11/3/06	
12		Form, Reinforce, Pour Ground I	14 days	Fri 10/27/06	Wed 11/15/06	
13		Substructure Complete to Grad	0 days	Wed 11/15/06	Wed 11/15/06	
14		Form, Reinforce, Pour Levels 2	72 days	Thu 11/16/06	Fri 2/23/07	
15		Form, Reinforce, Pour Roof	10 days	Mon 2/26/07	Fri 3/9/07	
16		Penthouse Structure	5 days	Mon 3/12/07	Fri 3/16/07	
17		Superstructure Complete	0 days	Fri 3/16/07	Fri 3/16/07	
18		Light Gauge Framing at North &	22 days	Fri 3/9/07	Mon 4/9/07	
19		Curtainwall at 11th St. Elev.	51 days	Fri 3/9/07	Fri 5/18/07	
20		Garage Interiors	75 days	Fri 3/16/07	Thu 6/28/07	
21		MEP in Penthouse	89 days	Fri 3/23/07	Wed 7/25/07	
22		Curtainwall at NY Avenue	52 days	Fri 3/30/07	Mon 6/11/07	
23		Penthouse Roof and Main Roof	24 days	Fri 4/6/07	Wed 5/9/07	
24		Elevator Installation	91 days	Mon 4/16/07	Mon 8/20/07	
25		Façade and Roof Complete	0 days	Mon 6/11/07	Mon 6/11/07	
26		Main Lobby Construction	55 days	Tue 6/12/07	Mon 8/27/07	
27		Typical Core Construction Floor	28 days	Tue 7/10/07	Thu 8/16/07	
28		Tenant Full Access	0 days	Mon 7/2/07	Mon 7/2/07	
29		Inspections	10 days	Tue 10/2/07	Mon 10/15/07	
30		Substantial Completion	0 days	Mon 10/15/07	Mon 10/15/07	



Project: 1099 New York Avenue
Date: Wed 4/9/08

Task		Progress		Summary		External Tasks		Deadline	
Split		Milestone		Project Summary		External Milestone			